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PRELIMINARY REVISED

REPORT OF COMMITTEE ON

ENGINEERING

The President's HIGHWAY SAFETY CONFERENCE

Held in

WASHINGTON, D. C.

JUNE 1, 2, and 3, 1949

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Report of Committee on

Engineering

GENERAL ASPECTS

Since the President's Highway Safety Conference of 1946, the urban and over-all traffic-fatality rates have declined. The rural rate has risen, however. And the over-all trend reversed in the early months of 1949—the fatality rate was higher during the first quarter of the year than in the same period of 1948. This reversal and the alarming annual accident toll as well constitute a pressing challenge to the engineering profession.

Engineers have been striving for many years to provide vehicles, roads, and operational control that will enable private motorists, commercial-vehicle operators, passengers in public conveyances, and pedestrians to reach their destinations conveniently and safely. Highway, automotive, and operations engineers alike have given special attention to two considerations—human behavior and physical conditions of the highway and the vehicle. Their joint efforts are paying significant dividends in the saving of lives and the prevention of injuries and property damage.

A far more intensive use of motor transport is certain in the future. To accommodate the mounting traffic volumes by superimposing adequate and safe transportation arteries on the existing street patterns will continue to be exceptionally difficult and costly in metropolitan areas. Yet it is likely that the creation of these arteries, plus greater use of public transit, will be necessary if cities are to be maintained as economically sound units.

Accident Factors

Causes of street and highway accidents lie in human behavior and in external conditions. The latter are particularly susceptible to engineering attack. To the extent that changes in external conditions can make human errors and misjudgments less likely and less hazardous, this approach will have success.

Drivers who have more than their share of accidents are rare, for accident-prone individuals are comparatively few. It is among the great bulk of drivers who ordinarily use reasonable care that nearly all accidents occur. They happen more or less at random among the driving population, involve every conceivable kind of person

with every degree of driving skill, and take place in every imaginable way. To this majority of reasonably careful drivers, engineering improvements offer great promise of accident reduction.

Obviously engineering control methods cannot make roads and vehicles foolproof, nor proof against reckless or criminal acts, nor totally immune from accidents. Emphasis should, therefore, be on engineering that will increase safety for the mass of good, bad, and indifferent drivers who have no especial proneness to accidents nor criminally reckless tendencies.

Accidents may occur under any set of conditions. But if vehicles, roads, and control procedures and devices are designed to fit conditions of use and known patterns of human behavior, physical conditions will be provided under which, it is not too much to expect, accident frequency and severity will be greatly reduced. In furthering desirable physical conditions, traffic-control devices such as those prescribed in the Manual on Uniform Traffic Control Devices are of great value and reasonably adequate. Where their use is warranted from an engineering standpoint, they are recommended. It must be remembered, however, that when misused, they cause irritation, delay, congestion, and accidents. This equipment, furthermore, is of little benefit without public understanding and support or without enforcement of attendant regulations.

Responsibility of the Highway Administrator

An appraisal of the existing organizational structure and its functions should be made by the highway administrator to determine whether the necessary sustained program of engineering analysis of traffic accidents is being efficiently and effectively conducted. The appraisal should reveal whether the highway department (State or local) is so organized that:

1. Every serious accident is analyzed to see whether any road feature or deficiency contributed to it.
2. The results of the analysis are applied to the correction of the condition.
3. The results are also considered in relation to design standards and practices, maintenance practices, and traffic regulation and control.

Engineering analysis of all serious accidents requires an adequate unit in the department charged with this function, and the closest possible liaison between this unit and the units responsible for design, maintenance, and operations.

Generally better coordination and cooperation between highway and enforcement departments also are needed. The highway administrator can advantageously help to perfect a closer liaison. Periodic conferences, for example, have proved of inestimable benefit to both agencies for the discussion of mutual problems. Properly instructed,

the police can do many things—such as enforcement against overweight and oversize—to conserve highway investment and insure effective safe highway use.

The collection and analysis of accident records plays a fundamental role in the success of several phases of safety effort. The highway administrator has an obligation to cooperate with enforcement officials and others in seeing that a qualified agency performs this function. Since in many States the initial investigation and reports are made by the police, it is highly desirable that the special needs of the engineer as to precise accident location and other roadway and traffic details be recognized by the police and the agency responsible for collection and analysis of accident records.

Responsibility of the Engineer

The responsibility of the engineer for efficient and safe highway transportation is far greater than has generally been realized, even by many engineers. Indeed no profession can do more for highway safety—and few can do as much.

The engineer's responsibility is to provide roads and vehicles safe for reasonable use. The motor-vehicle driver is entitled to a factor of safety that will give him substantial protection against hazards over which he has no control—hazards such as the acts of other drivers and of pedestrians, physical features of the highway and vehicle that limit visibility or otherwise endanger the traveler, inadequate signing, and uncontrolled or unrelieved congestion.

A typical problem in safe highway design concerns vehicle speeds. Important basic design data are the speeds at which reasonable drivers will operate under good driving conditions. It has been found for instance, that when the only limitations on speed are the capability of the machine and the desire of the driver, the great majority of drivers want to make "good time" but only about 15 percent exceed a reasonable and safe maximum speed. Under these conditions speeds range from 25 to 80 miles per hour, but only 15 percent exceed 55 miles per hour and only 13 percent go slower than 35. The average speed is 45. The application of data of this type to road design is one engineering approach to safety.

A major possibility for traffic-accident reduction through safety engineering lies in making highway use safer during the hours of darkness. Though less than a third of the travel is at night, about 65 percent of the traffic fatalities and 48 percent of all traffic accidents occur after dark. More adequate street and highway lighting at properly selected locations, and better vehicle lighting, would pay large dividends in the saving of lives and reduction of property damage.

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Fortunately engineering leaders are now giving greatly increased emphasis to their inescapable responsibility for safe and efficient highway transportation.

A recent publication, Traffic Engineering Functions and Administration,[1] prepared by a Joint Committee representing the American Association of State Highway Officials, The American Public Works Association, and the Institute of Traffic Engineers, is a most valuable guide to effective engineering and administrative practice in the traffic field.

The Engineering Attack

The engineering approach to highway safety is high-lighted by long-range planning and orderly annual programs of highway improvement, maintenance, operation, and administration so that lasting results can be achieved, beginning at the earliest possible moment.

In planning highway improvements, determination of the type of highway to be built in any given location depends fundamentally on traffic requirements and funds available. For thousands of miles of roads, the immediate complete improvement is beyond the capacity of the public purse; yet in congested regions, reasonable taxes—if used for highway purposes—can provide multilaned, divided roadways, grade separations, controlled access, lighting, and all the justifiable safety features yet devised.

Because roads and streets can be made much safer through the application of safety-engineering technology, the most feasible road-engineering solution to the accident problem is to build into a road, within the limit of available funds, all the proved safety features applicable to its type or class. And the ideal time to do this is during the original construction stage.

This will involve due attention to available facts concerning both prevailing and anticipated driver behavior and vehicle characteristics. The resulting improvements needed for safety will range from treatment of specific, hazardous spots on existing improved roads, to new construction of controlled-access express highways.

But since all roads and streets cannot be made foolproof through engineering design, the engineering solution that may be used most extensively at present is control of traffic operations through regulation of road usage. This method consists of the proper use of signs, signals, markings, islands, and lighting. Because of the constant increase in traffic accidents in small communities and rural sections, there is particular merit in wise regulation and control in these areas.

Engineering attack on automotive design also offers possibilities of accident reduction. The great number of accidents resulting from

[1] Available from the Public Administration Service, 1313 East 60th St., Chicago 37, Ill. Price $2.50.

winter driving hazards points up the problems of skidding and visibility. These are as challenging to the automotive engineer as to the highway engineer.

Greater safety on the highway may be attained through engineering methods, but this will require more attention to the accident problem, not only by engineers but by administrators and public officials as well. There has been a general lack of appreciation of the extent to which accidents can be reduced by application of engineering principles and techniques.

Opportunity to Improve Engineering Contributions to Safety

It is not enough to say that greater attention must be given to engineering for safety. All designs of roads and vehicles and all operational plans must be subjected to appraisal of the safety factors, both physical and economic. But who is to do it?

Much engineering knowledge is available in this area of highway engineering, but it has not yet had the extensive application so vitally needed. The reason is natural enough. Legislative and highway-administrative officials are under tremendous public pressure to produce a large mileage of highway improvements. This makes for a continuing conflict with the engineer as he strives to employ the more modern standards of design and work toward safer operating conditions.

Added emphasis on the application of safety fundamentals is needed at other places too. In education, and properly so, undergraduate curriculums are heavily laden with the fundamentals of engineering science and allow little or no room for specialized courses in safety. In existing courses in highway design, construction, and operation, however, there is excellent opportunity to stress the importance and basic principles of safety.

If highway traffic safety is to attain maximum benefits from engineering measures, engineers must be trained for traffic and safety work, given experience through well-organized in-service activities, and placed in responsible positions at key points in highway organizations with reasonable assurance that they may find professional opportunity, compensation commensurate with their ability and experience, and continuity in the tenure of their positions.

Safety cannot be achieved however, as an end in itself. Rather it is the byproduct of correct action. In the final analysis, it is the well-organized State or local highway department, with sound engineering and administrative methods, that will make a significant contribution to highway safety. The department should be a balanced organization, with adequate staff and authority to perform its official functions and with every branch conscious that proper performance of its normal duties is the best possible way to contribute to highway safety.

A pressing need at this time is for a greatly increased number of well-trained, experienced traffic engineers and for a closer liaison among design, construction, maintenance, and traffic divisions. The training of specialists in traffic engineering requires time, but can be expedited by the establishment at engineering colleges of graduate fellowships in traffic and safety engineering. This, of course, will involve increased availability of funds for this training.

Parallel with the need for more traffic engineers is the urgency for stronger accident-record information, both in amount and quality. Most accident reporting has been aimed at control of the individual driver. An equally important objective, however, should be the exposure of deficiencies in highway or vehicular design, or characteristics of traffic flow that are likely to cause accidents.

In every jurisdiction—city and State—existing accident report forms should, therefore, be reviewed by engineering agencies responsible for roads and streets, to see whether they are suitable for the accomplishment of this second purpose. If not, they should be revised.

Specifically, the places where rural accidents occur need to be more exactly reported. Control sections into which most highway systems have been divided, and the roadside-station marker posts employed in some States, afford good identification for spotting accident sites more precisely.

There can be no doubt that an improved accident-report form providing more pertinent data on roadway conditions, and greater volume of better accident reporting, would be valuable aids to the engineer in determination of design treatments.

Intensive investigation and analysis also need to be directed to the disclosure of faults or defects in the design, material, or construction of the vehicles involved in accidents, or of their component parts, as well as to highway deficiencies, and these findings called to the attention of the persons in position to effect remedies.

To spur immediate corrective action, much could be done through intensive educational programs and through conferences for engineers. These might be arranged through cooperation among governmental authorities in charge of road and street work and other highway groups, vehicle manufacturers, educational institutions, and agencies concerned with safety.

A noteworthy example of great potentialities is the program adopted by the Institute of Transportation and Traffic Engineering established at the University of California by the State Legislature. This program is recommended for consideration by other States and universities. It is a practical illustration of *how* to provide needed training for engineers; *how* to get important highway investigations, analyses, and researches undertaken; *how* to arrange valuable conferences and cooperative enterprises between governmental agencies

and other qualified organizations; and *how* otherwise to improve engineering contributions to safety.

Value of Research

Up to this point emphasis in this report has been on action through application of proved techniques and procedures. From the long-range viewpoint equal emphasis is warranted on the need for basic research in the highway and automotive fields. A pay-off in safety comes from constant alertness to the possibilities of applying the principles discovered in basic research to design and practice. The development of the modern all-steel vehicle body ably demonstrates the value of research in the automotive field. The safety afforded by the present-day vehicle body has been provided only as a result of continued research. The steel body is an example of secondary results derived from research and development in one field that become primary benefits in the field of highway safety.

Another illustration is the lowered cost of grading in highway construction that resulted from research. This lowered cost makes possible the building of roads with better line and grade and more adequate sight distance, thus greatly promoting highway safety.

There are many areas of engineering for safety in which information is nowhere near complete and in which the search for new knowledge should be greatly intensified. Of cardinal importance, for example, is the study of driver behavior and characteristics in relation to engineering problems. Yet in this area of research the surface has scarcely been scratched.

The relating of highway factors to accidents has only recently begun to receive the attention it deserves, and indications are that future research will prove highly productive.

Much more needs to be learned about practical capacities of roads and streets under various conditions. The forthcoming report of the highway capacity committee of the Highway Research Board will fill a pressing need in the field of safety.

The need for improvement in methods of lighting the highway from moving vehicles with safety to all, is generally acknowledged. Noteworthy of increased attention to the need and value of research is the setting up by the Conference of an advisory group on highway safety research.

Agencies that can conduct researches to fill in the gaps in our knowledge are urged to do so, for only through application of research findings can many of the fundamental causes of accidents be effectively dealt with. Interested groups should contact the Highway Research Board. Through its Research Correlation Service for the American Association of State Highway Officials, it is in position to be of practical service.

Effect of Legal and Regulatory Provisions

Legislatures and regulatory bodies have promulgated many requirements concerning sizes and weights of commercial vehicles and their design, construction, and accessory equipment. Frequently these requirements have been impractical and compliance has, therefore, been difficult or impossible. In some instances, the design of vehicles has been adversely affected and the principal intent of the law or regulation has not been realized. The result has been, probably by inadvertence, to make these vehicles less safe for operation or to cause some adverse design changes.

It is strongly urged that legislative or regulatory bodies obtain competent and impartial engineering advice when undertaking the establishment of provisions affecting the design and construction of motor vehicles or their appurtenances. Engineering counsel would determine whether the language of the proposed regulation would accomplish the purpose intended and insure against new evils.

Other statutory encumbrances, the outgrowth of legislation adopted before the development of present patterns of motor-vehicle use, have created difficulties in the acquisition of right-of-way for modern facilities. Legislatures need to adopt and courts to approve provisions for control of access to high-traffic-volume routes. Similar impediments prevent the acquisition of sufficient right-of-way width or area at intersections. These right-of-way inadequacies contribute to an accident rate that is higher than average on recently improved highways. Legislative action is urgently needed in many places to open the way for fully modernized routes.

Assuring Continuity of High-Grade Highway-Transportation Engineering

A major challenge to highway transportation must now be met. Sound business principles demand that the expenditure of billions for highways be under the direction of qualified engineers. Many of the present highway engineering leaders are close to retirement age. As trusted lieutenants take their places and others move up to higher positions, there must be assured a continuing influx of intelligent young engineering graduates. Yet a recent survey by the American Association of State Highway Officials shows a *deficiency of some 9,000 engineers* in State highway departments alone, and reveals a lamentable lack of interest among current civil-engineering students in pursuing a highway career.

Lack of proper engineering personnel in county, city and other local road agencies is notorious. Political interference with the continuity of highway engineering management is another serious personnel factor which often has devastating effects on highway safety. Ways and means must be found and applied promptly to correct this serious and potentially disastrous situation.

THE HIGHWAY

Engineers have developed certain principles in highway design, construction, and maintenance that, with proper application, unquestionably enhance highway safety. Research and experience are constantly adding to, and refining, these principles. In the interest of safety these principles should be observed to the fullest extent that available means will permit in future design and construction of all highways, and in maintenance and reconstruction efforts.

The highway probably cannot be expected to be entirely accident-free, of course. Regardless of its adequacy a certain proportion of vehicles and their drivers will always be found at fault.

The highways of the United States have been built under sustained pressure to provide a large mileage of improvement for rapidly expanding motor-vehicle usage. They are an example of excellent engineering to provide the most for the least expenditure—the consequence of insufficient funds and fixed mileage goals administratively determined.

But this approach resulted in an extensive highway network built to low standards. Additional funds are therefore needed to convert many miles of our highways to an adequate safe design.

Considerable time will be required to reconstruct those parts of our highway mileage that have been rendered prematurely obsolete, and to a degree unsafe, by the rapidly increasing numbers of faster and heavier vehicles. And while rebuilding to modern standards is in progress, traffic will certainly continue to increase. Practicable means must therefore be employed to reduce the dangers of the obsolete mileage. These means include operational controls and guides, and modest physical alterations. Principal measures of these types are enumerated in the following section, The Operation.

Safety in travel is obviously dependent upon intimate coordination of the features discussed separately in this section on the highway and in the operation section. Urgent problems in both categories need rapid solution, particularly on highways in rural areas and on their extensions into and through small communities. On these highways built to low or inadequate standards, the coordination of both lines of approach is especially important in safety achievement.

Long-Range Planning Means Safer Highways

A great lesson of the past in American highway development is that roads and streets built only for today's traffic needs, and not for to-

morrow's, too often become congested and accident-ridden long before their physical life is ended. Too frequently an entirely new location must be found in order to modernize the road. Long-range planning of future construction and reconstruction is thus of foremost importance for safety, traffic adequacy, and permanence of investment.

Promoted in part by adequately meeting highway needs, safety must begin in planning and planning must be based on facts. Since a comprehensive program of highway construction will necessarily take many years, the need for planning data will be a continuing one.

Among the major planning objectives should be the collection, analysis, and utilization of reliable accident data as related to highway elements. By concentrating on this phase of highway research, knowledge regarding highway safety can be expanded more rapidly. As new data are analyzed it can be better demonstrated that "built in" safety features do pay, thus making possible the acquisition of more adequate funds.

Another major objective must be to formulate a long-range program for new highways, with proper standards adopted at the outset for each class of road.

In this way, through regular yearly construction programs, each fitting into the carefully planned whole, our roads and streets can eventually offer the maximum of lasting "built in" safety.

Planning begins with an inventory of the condition and extent of existing roads and streets, their classification according to type of service rendered, and an integration of road classes into road systems. This preliminary work is well advanced in rural areas, with primary, secondary, and tertiary roads generally well identified, but urban systems are less segregated. Few clear-cut urban planning programs are found that implement the classifications and provide for consistent yearly improvement progress. There is standing need for a coordinated program between State and local officials, so that plans for local improvements and their financing are kept abreast of Federal-State plans for arterial-highway development.

Important new tools are available through the Federal Aid Highway Acts of 1944 and 1948, the State Highway Planning Surveys, and the urban origin-destination traffic surveys. More than 100 cities have already made comprehensive origin-destination traffic surveys and about 125 cities have produced preliminary engineering reports analyzing arterial routes, streets, parking, and related planning factors.

Intensive studies conducted since 1935 in the Nation-wide State Highway Planning Surveys have shown that a relatively small mileage of roads and streets carries extremely heavy daily traffic densities, with a corresponding heavy concentration of congestion and accidents. The most serious accident factor on these routes is marginal conflict at intersections and pedestrian crossings, in movements to and from

roadside establishments, and in roadside parking. Unless control measures are adopted at the outset, the very existence of heavy traffic guarantees roadside development of the type that causes hazards and seriously impairs the road's capacity.

Roadside control measures are of major importance in planning the development of primary roads and streets. Without them neither safety nor traffic capacity can be long assured. Such measures include: (1) legal control of access, (2) marginal-land acquisition, (3) land-use controls of various kinds, and (4) acquisition by the highway or planning agency of the right to limit private use of roadside land to approved activities. The latter are activities that will not create hazards nor prevent later widening of the road or addition of other design refinements at reasonable cost.[2]

Relation of Highway Design and Accidents

It is generally known that in some respects highways of low standard promote accidents. But prior to about 1945 little comprehensive data had been analyzed to show the relation between accidents and highway design features. Now several comprehensive studies have been undertaken. Values in the preliminary report from one study indicate the scope and type of data that will be available. In this study[3] sponsored jointly by Public Roads Administration and the National Safety Council, data were collected from 10 States, covering over 9,000 accidents occurring on almost 4,000 miles of major rural highways. Figures 1 to 4 show some of the findings in terms of the average accident rate (all reported accidents) per million vehicle-miles.

The upper portion of figure 1 demonstrates that on straight 2-lane highways the accident rate rises as traffic volume increases up to a point where accidents suddenly decrease. The drop in accident rate for volumes over 9,000 vehicles per day is believed to be the effect of congestion, the slower, impeded speeds of traffic resulting in less-hazardous operation.

Pavement widths on straight sections of 2-lane highway directly affect the accident rates, as shown in the lower portion of figure 1. Other studies prove that factors such as type and width of shoulder, and lateral clearance to walls, poles, and similar roadside features, must be considered jointly with pavement width in evaluation of highway design.

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[2] Public Control of Highway Access and Roadside Development, by D. R. Levin, Public Roads Administration, 1947. Available from the Superintendent of Documents, Washington 25, D. C., price 35 cents. Control of Access in Urban Areas, by J. Barnett. 1949 American Road Builders' Association Proceedings.

[3] The Relation of Highway Design to Traffic Accident Experience by D. M. Baldwin. Convention Group Meetings, 1946, American Association of State Highway Officials.

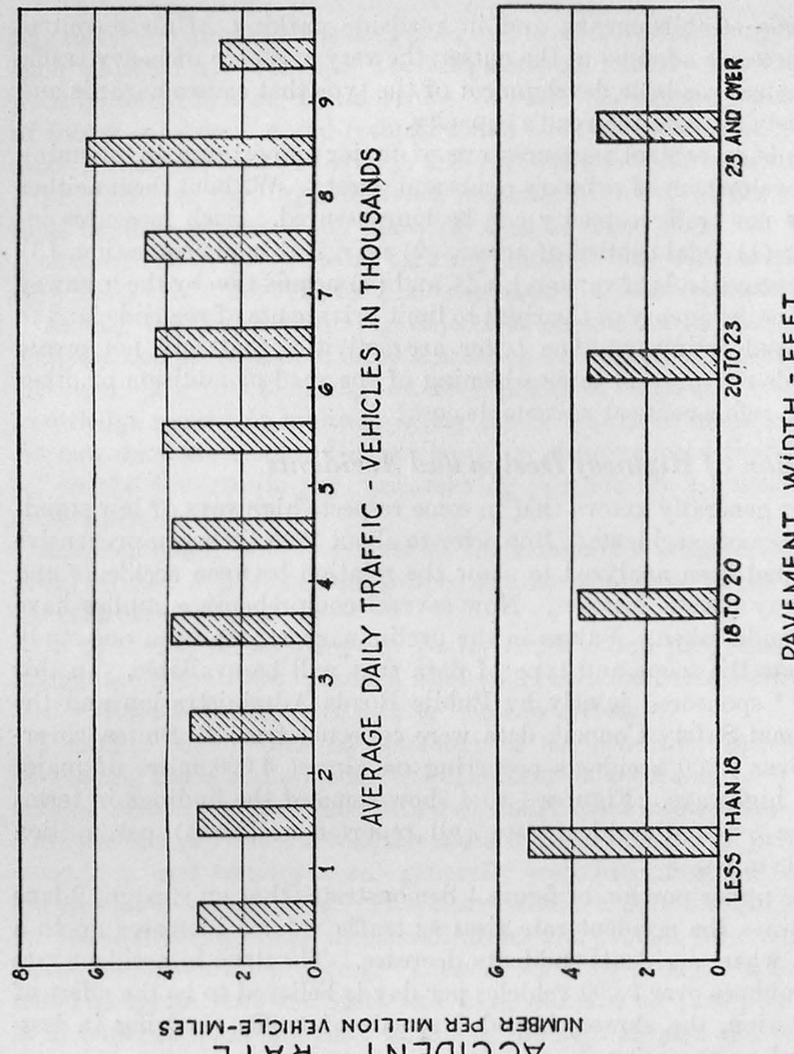

FIGURE 1.—Accident rate on straight sections of rural two-lane highways.

Consideration of figures 1 and 2 indicates that the accident rate on curves is not a great deal different from that for straight sections. But there is considerable variation in the rate with curve sharpness and frequency. Figure 2 illustrates that where curves are infrequent they are more hazardous than where they are part of a continuous winding alinement. At isolated curves the rate shows a marked increase with curve sharpness.

At structures the accident rate varies inversely and sharply with the width of structure as compared with the width of the approach pavement, figure 3. The wider structures had an accident rate only

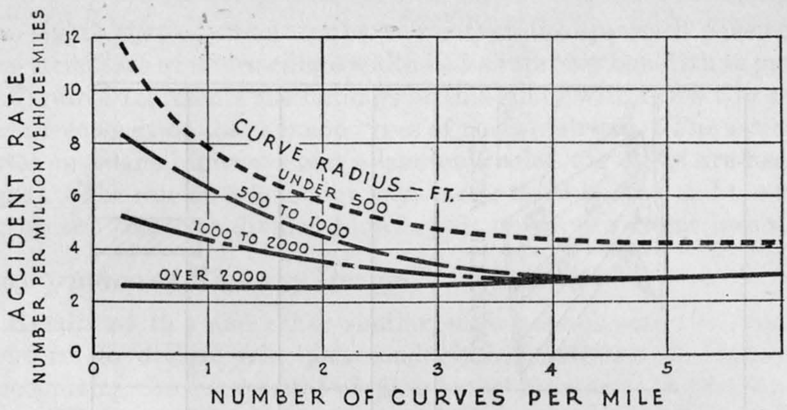

FIGURE 2.—Accident rate on curved sections of rural two-lane highways.

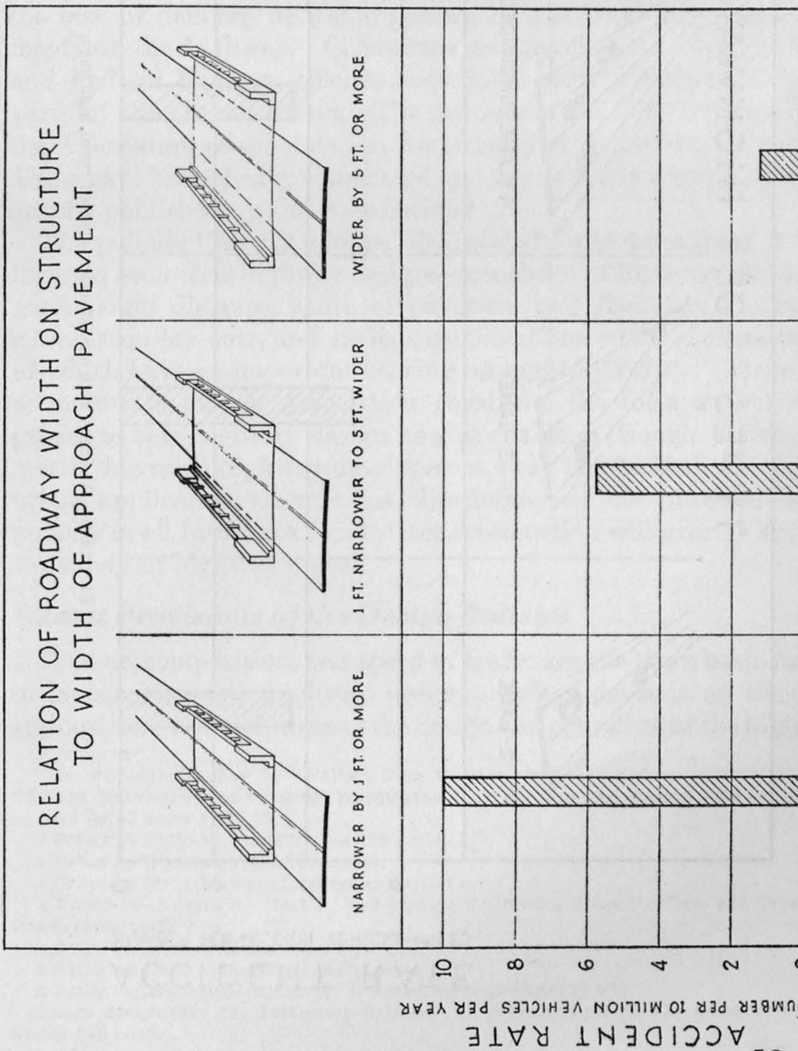

FIGURE 3.—Accident rate at structures with two-lane roadways less than 30 feet wide.

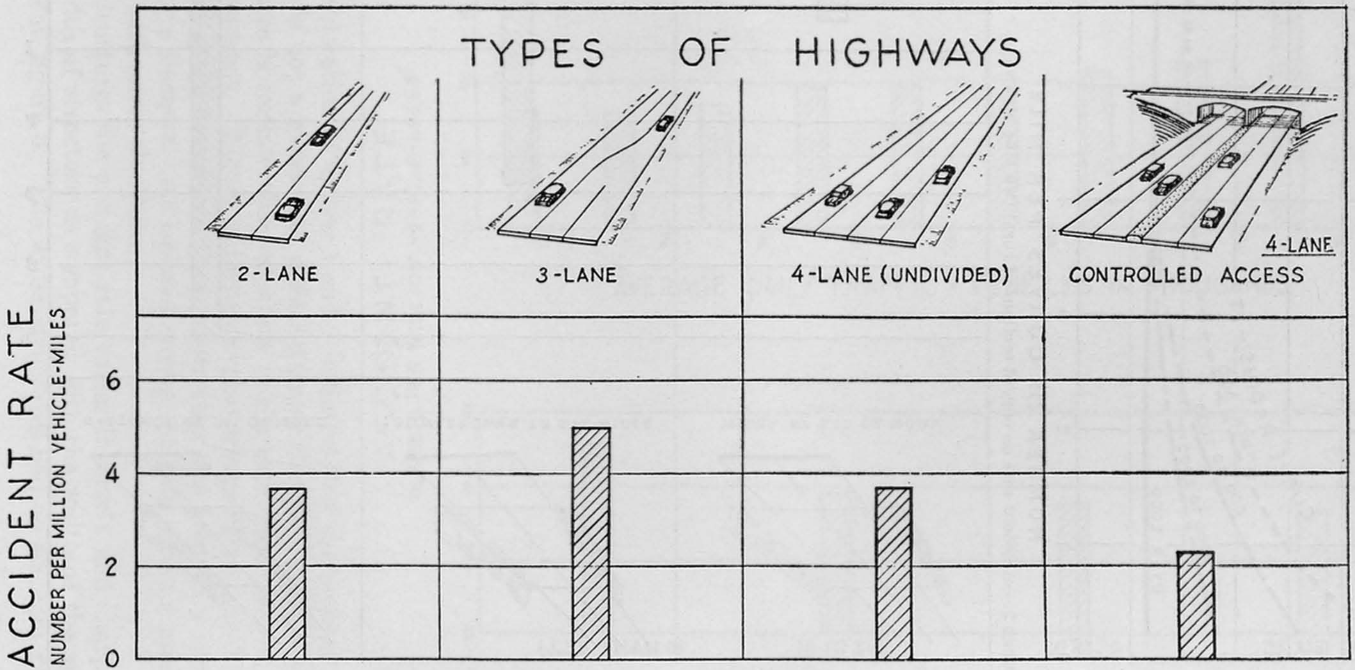

FIGURE 4.—Accident rate on different types of rural highways.

one-eighth that of structures narrower than the approach pavement, and structures of intermediate width had a rate only one-fifth as great.

Figure 4 represents the findings of this study with respect to accident frequency on the common types of rural highway. The accident rates on 2-lane highways and 4-lane undivided highways are nearly equal. The rate on 3-lane highways is one-third higher, and the rate on controlled-access divided highways is about 40 percent lower.

Importance of Highway Design

Results of this and other similar studies emphasize the need to conform to design principles conducive to safe use of highways. Recognizing the importance of design the American Association of State Highway Officials 12 years ago assigned to a special committee the task of defining desirable policies or standards for various elements of the highway. Committee membership consisted of State and Federal highway officials acquainted with conditions in many parts of the United States. The committee has since proposed and the Association adopted design standards and several design policies. These have been clearly enunciated and explained in a series of monographs published by the Association.[4]

The policies thus far adopted deal mainly with principles of what is called geometric highway design—principles of highway alinement, grade, sight distance, width of pavement and shoulders, clearances, intersection lay-outs, and various combinations of these elements, all of which have an important bearing on highway safety. These pronouncements of the Association constitute the most authoritative guides to safe highway design now available. Though written primarily for rural highway development, they are decidedly useful for urban application as well. A discriminating use of these design policies in all future road and street construction will greatly improve the safety of highway travel.

Salient Provisions of the Design Policies

Volume, composition, and speed of traffic are the three basic factors to be considered in highway design. Safety depends on the joint application of these factors in the design and operation of the highway.

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[4] The monographs may be obtained from the American Association of State Highway Officials, National Press Building, Washington 4, D. C. Price of the complete set of seven policies listed below is $2.25.

A Policy on Highway Classification (50 cents).

A Policy on Highway Types (50 cents).

A Policy on Sight Distance for Highways (50 cents).

A Policy on Criteria for Marking and Signing No-Passing Zones for Two- and Three-Lane Roads (50 cents).

A Policy on Intersections at Grade (50 cents).

A Policy on Rotary Intersections (50 cents).

A Policy on Grade Separations for Intersecting Highways ($1.00).

Design Standards: (1) Interstate System, (2) Primary System, (3) Secondary Feeder Roads (15 cents).

In the evolution of modern design, increases in traffic volume, wider commercial vehicles, and higher operating speeds have brought successively wider traffic lanes. Ten feet has been the standard width in many States but the trend is definitely toward more liberal widths for all principal routes. Eleven-, twelve-, and thirteen-foot lanes have been employed in the more modern improvements. There can be no denial of the added safety afforded by the greater lateral clearances to traffic in adjoining lanes. More liberal clearance helps to prevent side-swiping accidents. It also increases the ease and comfort of driving, with consequent lessening of fatigue which in itself contributes to many accidents.

Highway shoulders are another item for special consideration in modern design. A primary function of shoulders is to provide areas for use in an unusual traffic situation or in the event of vehicle disability. Sufficient width should be available to permit such operations as changing a tire without undue hazard. Other characteristics of good shoulders include a smooth, even surface substantially flush with the pavement edge, and ability to support satisfactorily, occasional moving vehicles that must leave the main portion of the roadway because of mechanical trouble, traffic circumstances, or other difficulty.

The need for emergency stopping space increases with traffic volume. It is greatest on multilane facilities in urban areas. Recent information reveals one vehicle break-down to every 5,000 to 9,000 vehicle-miles. Thus, on a mile of highway carrying 10,000 vehicles per day, at least 1 and probably 2 break-downs will occur per day. In the absence of usable shoulders, they can seriously impede the flow on all lanes during peak-hour traffic.

Sidewalks are another design feature with important safety value in suburban and rural areas where pedestrians in considerable number walk along highways carrying moderate to heavy volumes of traffic.

On highways having four or more lanes, experience has proved the safety value of physical separation of traffic by direction of movement. This virtually eliminates one of the most serious types of accident, the head-on collision. Careful placement of shrubs or small, slow-growing trees in the central dividing area and difference in elevation of the two roadways are effective in reducing glare from headlights. Wide separation areas are highly desirable, but they need not be of uniform width. At crossroads the width and length of openings in the separation area should be adequate to provide protection for vehicles crossing or turning to or from the divided highway.

Many accidents occur because drivers do not see possible sources of danger until too late. At all points on the highway the clear view ahead should be sufficient to enable the operator to perceive the need for an emergency stop and to stop before reaching the critical point.

The required length of this clear sight distance is dependent on travel speed, braking ability of the vehicle, the friction characteristics of the road and tire surfaces, and the reaction time of the driver. This minimum stopping sight distance has been determined for various travel speeds, and values are included in the design standards.

In addition to minimum stopping sight distance which must be provided at all points along a highway, sections with sight distance adequate for overtaking and passing vehicles also must be provided on 2-lane roads. To be entirely safe, a driver intending to pass should be able to see ahead a distance sufficient to permit him to start and complete his passing operation without interference, even though a car proceeding in the opposite direction comes in view as soon as the passing is begun.

Passing sight distances have been determined for various speeds and are included in design standards. The frequency at which these longer passing-sight-distance sections should be provided is dependent on demand for passing, which in turn is related to volume, speed, and character of traffic to be accommodated. Except in flat terrain, it usually is not feasible to build a highway affording passing sight distance at all points. To minimize passing attempts where they would be hazardous, modern standards include measures for determination, identification, and designation of no-passing zones by appropriate marking.

The current trend in passenger-car design is toward lowering the car height and the driver's eye level. This has some adverse effect on sight distance over hill crests. Some compensating modification of present sight-distance standards will probably be required if this trend in vehicle design is continued.

Conflicts and dangers at highway intersections at grade have been the subject of much study. Elimination of these hazard points by grade separation is the most positive remedy, but for reasons of cost can be employed only infrequently. By relatively minor treatment, however, improvements in safety and operation can be assured at many intersections.

Among the principles covered in the design policies are those for the proper lay-out of the many forms of intersections at grade. Design data for intersection sight distances also are included.

As one example, figure 5 illustrates the minimum sight-distance requirements at intersections where traffic on a cross road is controlled by a stop sign. Without a clear sight distance of the value indicated for the corresponding travel speed on the major highway, collisions are likely.

Other design features assuring safe operation are described in policies on rotary intersections and grade-separated intersections. These higher-type intersections eliminate the customary cross-traffic move-

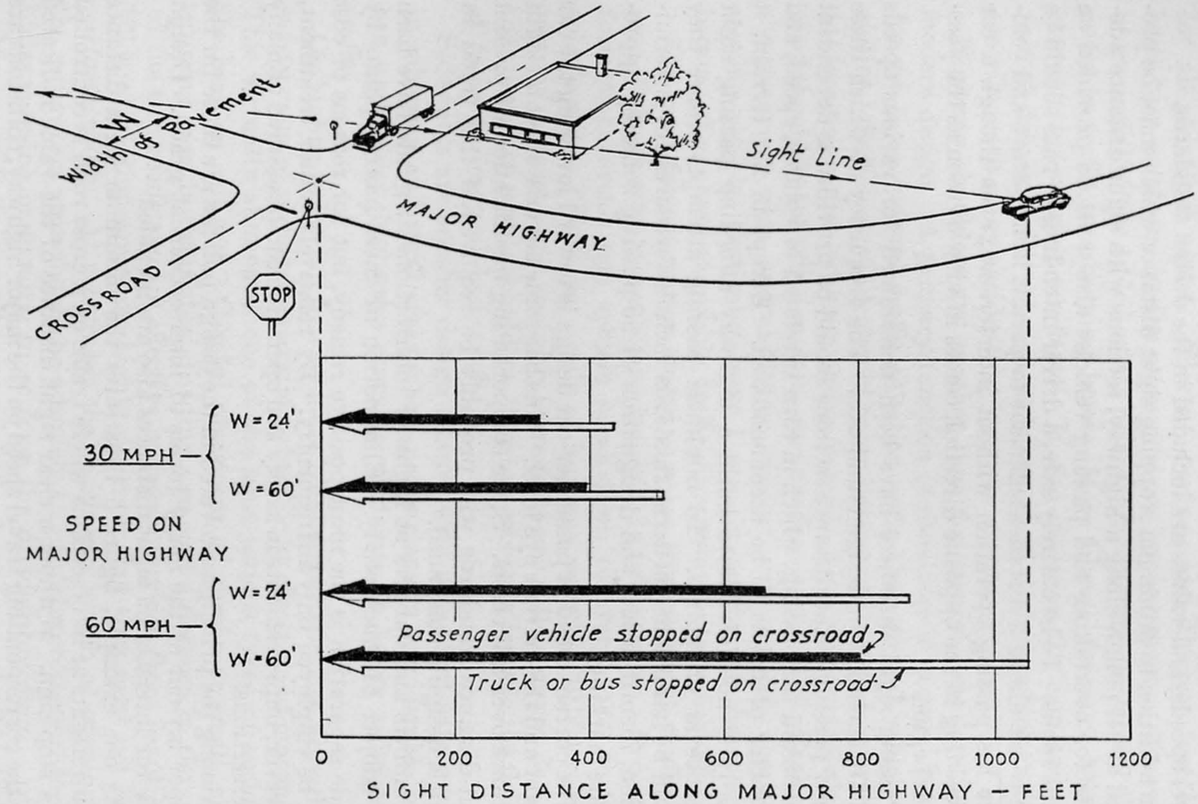

FIGURE 5.—Required sight distance at intersections where traffic on cross road is controlled by stop sign.

ments and involve less delay to vehicles. There is a multiplicity of detail in their design. Particular care is warranted to avoid the creation of confusion and hazard by requiring the driver to follow unnatural and complicated courses to reach a desired exit point.

Interstate Highway Standards [5]

The newly designated 40,000-mile national system of interstate highways will run to and through all principal population centers and, in general, serve the heavier and more important traffic movements. To provide the high type of traffic service desired on this system, the routes included must be built to higher and more refined standards of design than have heretofore been in general use.

A distinguishing characteristic of these new highways, both city and rural, is that they are planned for the purpose of expeditiously handling heavy or long-range traffic. This makes it essential to maintain a rather strict control of access in order that the traffic stream may move safely and without delaying and hazardous interruptions from crossing, entering, or turning vehicles.

Another outstanding feature in the design of the interstate system is the elimination of all railway-highway grade crossings where there are two or more main-line tracks, at single-track crossings where six or more regular train movements occur daily, and at other crossings with fewer train movements whenever economically justified. Highway-highway grade crossings are to be eliminated where a study of traffic delay, hazard, and inconvenience indicates the economic practicality of constructing a separation. As a control in evaluating the adequacy of present highways on the interstate system, grade separation of rural intersecting highways is considered necessary under these circumstances: where the sum of the two-direction traffic volumes on both intersecting roads exceeds 2,000 during the design peak hour,[6] and the lower volume on either road is at least 500 vehicles during this hour. Highway crossings remaining at grade are to be equipped with devices that will protect and expedite the principal traffic movement.

Alinement, sight distance, and grades are to be properly balanced and designed for speeds of 50 to 70 miles per hour in rural areas, depending on topography, and for 50 miles per hour in urban areas. Traffic-lane widths are specified at a minimum of 11 feet for the lowest traffic volumes and 12 feet for the moderate-to-heavy volumes.

Use of divided highways is planned for all sections requiring more than 2 lanes; but it is estimated that on at least two-thirds of the rural mileage of the system, the present traffic volumes can be accommodated on 2-lane highways of modern design. Where a divided section is not

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[5] See footnote 4.

[6] Generally, the design peak hour is the hourly traffic volume exceeded only 30 hours out of the 8,760 hours in a year.

warranted immediately, the initial improvement should be integrated with plans for the ultimate development and the full right-of-way width acquired. Desirable right-of-way widths for 2- and 4-lane roads have been set at 220 and 250 feet, respectively.

Safety Benefits from Improved Highway Design

The value of adequate design to safety has been substantiated by accident studies on major highways in nearly all sections of the country. Following are selected examples of results from these studies:

Michigan.—The Detroit Industrial Expressway practically parallels U S 112 for about 15 miles westward from Detroit, and both carry a heavy volume of mixed traffic, including large commercial vehicles. U S 112 is a divided highway for much of its length, but in contrast with the Expressway, it does not have control of access. U S 112 is lighted for a portion of its length, but there are no lights on the Expressway. For 1946, comparative accident rates per 100 million vehicle-miles, including both injuries and fatalities, are:

	Day	Night	24-hour total
US 112	517.8	891.5	625 3
Detroit Industrial Expressway	69.9	143.4	91.1

Also in the Detroit area, the Davison Expressway is an outstanding example of safety benefits incident to modern design. It is approximately 1½ miles in length, and is distinguished by a depressed central section for through traffic and parallel surface drives for local movements. All roadways are equipped with high-type street lighting. Table 1 contains a 4-year record of the accident experience and traffic volumes on this facility. Data are separated by the through and local roadways. Two features are worthy of notice. With more than four times as much traffic, the depressed section where access is strictly controlled, shows less than a third as many accidents as the surface drives which are subject to most of the customary intersectional and marginal interferences. The low ratio of night-to-day accidents is testimony to the safety value of modern street lighting.

California.—Four arteries of comparable length and traffic volume were studied. Two of these, Arroyo Seco Parkway and Riverside Drive, are characterized by grade separations, control of access, and use by passenger vehicles only. The other two have crossings at grade and free access. Comparative data are given in table 2.

Table 2 also gives data for all rural State highways of various types of design and traffic volumes.

The data show not only a large gain in traffic safety but greatly increased speeds on the improved facilities. While Wilshire Boule-

TABLE 1.[1]—*Comparison of traffic accidents, day and night, on the Davison Expressway*[2]

Location and type	1945			1946			1947			1948			4-year totals		
	Day	*Night*	*Total*	*Day*	*Night*	*Total*	*Day*	*Night*	*Total*	*Day*	*Night*	*Total*	*Day*	*Night*	*Total*
Depressed section (through traffic):															
Fatal	0	0	0	0	0	0	0	1	1	1	0	1	1	1	2
Injury	2	1	3	4	5	9	2	4	6	7	4	11	15	14	29
Property damage	6	7	13	13	6	19	20	12	32	30	18	48	69	43	112
Total	8	8	16	17	11	28	22	17	39	38	22	60	85	58	143
Average week-day 24-hour traffic volume		27,058			36,362			37,145			45,045			36,402	
Surface drives (local traffic):															
Fatal	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1
Injury	14	10	24	12	6	18	12	12	24	8	11	19	46	39	85
Property damage	39	28	67	50	24	74	69	74	143	66	65	131	224	191	415
Total	53	38	91	62	30	92	81	86	167	74	77	151	270	231	501
Average week-day 24-hour traffic volume		5,922			7,614			6,797			10,269			7,650	

[1] Source: Board of Wayne County Road Commissioners, Safety and Traffic Division, Detroit, Mich.

[2] Depressed expressway section extends from Lincoln Ave. east to Greeley Ave., 7,980 feet. Local-traffic surface drives (one-way streets) extend approximately 6,000 feet and are parallel to depressed expressway section.

vard compares fairly well with the controlled-access routes in the fatality rate, its accident rate is 5 to 6 times greater.

For the entire 7-year period 1941–47, the Arroyo Seco Parkway has an average record of 2 fatalities and 67 injury-and-fatal accidents per 100 million vehicle-miles.

TABLE 2.—*Mileage, traffic, and accident data for major California highways.*

	Arroyo Seco Parkway	Riverside Drive	Figueroa Street	Wilshire Blvd.	Rural State highways
Length, miles	5.80	3.50	5.35	4.65	Varies
Average speed, m. p. h.	40.2	40.1	17.2	23.3	Varies
1941 data:					
Average daily traffic	27,200	27,100	28,100	39,300	Varies
Fatality rate [1]	3.5	2.9	20.0	4.5	14.5
Accident rate [2]	48.6	49.1	371.8	253.9	117.4
1944 data:					
Average daily traffic	21,500	21,400	20,000	31,400	Varies
Fatality rate [1]	4.4	0	9.4	5.6	13.6
Accident rate [2]	37.4	40.2	331.3	234.6	98.6
1947 data:					
Average daily traffic	31,600	35,600	30,500	38,400	Varies
Fatality rate [1]	0	4	9	3	10
Accident rate [2]	103	114	407	267	106

[1] All fatalities per 100 million vehicle-miles.
[2] All injury and fatal accidents per 100 million vehicle-miles.

Connecticut.—Figure 6 presents comparable fatality rates per 100 million vehicle-miles for the period 1940 to 1948 on different types of Connecticut highways. The expressways and parkways are controlled-access facilities with grade separation. The parkways carry passenger cars only. The other highways are at grade and without access control.

The higher fatality rate of 3.4 on the parkways, as compared to 1.6 on the expressways, is believed due to design of the earlier Merritt Parkway without flush shoulders. Drivers are directed to cross a low, continuous curb at the right edge of the pavement when making emergency stops. But two-thirds of the Merritt Parkway fatalities from collision between vehicles have involved a standing vehicle, the curb having discouraged drivers from pulling over onto the available grass shoulder. The newer parkways are built with flush shoulders, but have not been in operation long enough for reliable accident-comparison data.

The Merritt Parkway in Connecticut and the parallel portion of the Boston Post Road (each about 37 miles in length) afford an unusual opportunity to compare the hazard characteristics of a modern 4-lane divided parkway with those of an earlier, conventional 4-lane undivided highway. This part of the Post Road passes alternately through villages or small cities and through relatively open country. Adjacent development frequently produces a large pedestrian movement along and across the road. Many highways intersect the Post Road at grade, with several of them carrying substantial traffic vol-

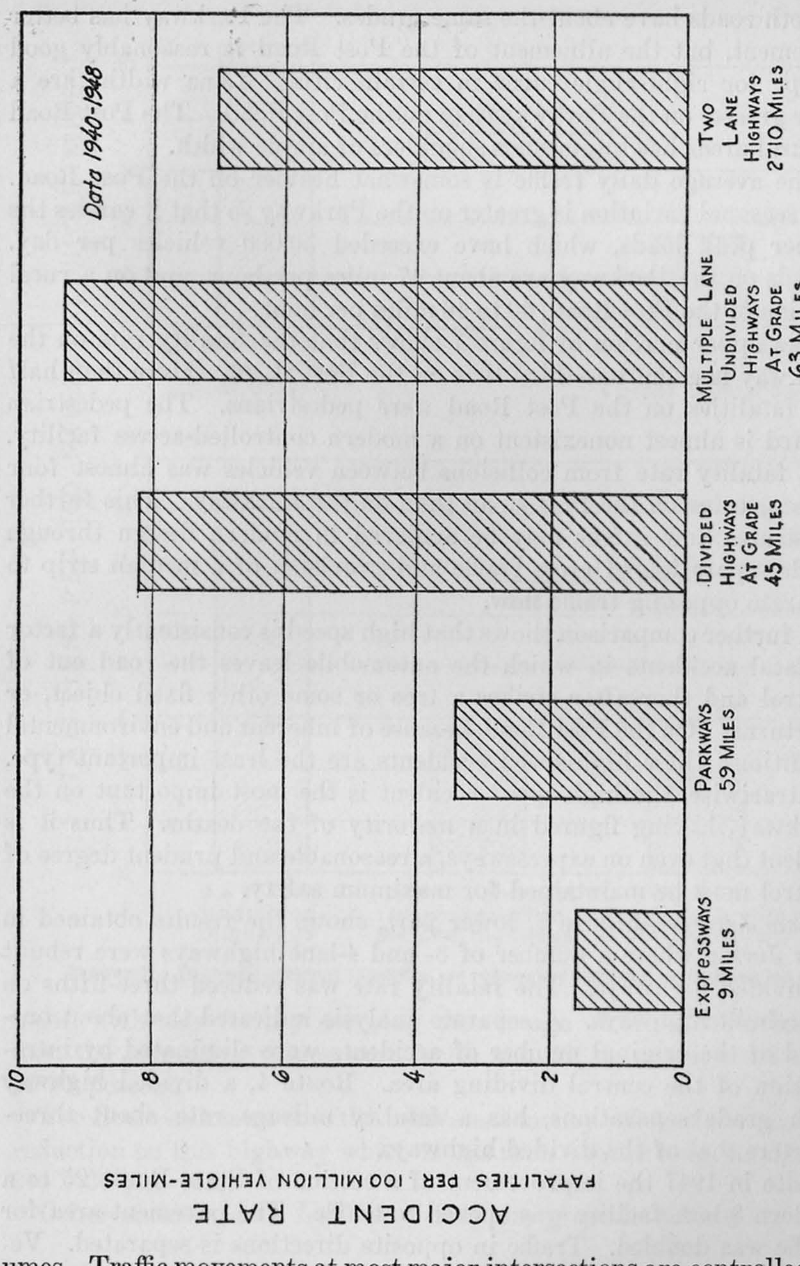

FIGURE 6.—Fatality rates on State-maintained highways in Connecticut.

umes. Traffic movements at most major intersections are controlled by signals. A mixed traffic is carried—about 75 percent of it is passenger cars.

The Parkway, in contrast, has all cross-traffic flows separated. There is no access from abutting property, and, consequently, little pedestrian traffic. Use of the Parkway is limited to noncommercial motor vehicles.

Other Areas.—The splendid system of controlled-access highways of the Metropolitan New York Parkway System, now consisting of 164 miles of multilane roadway, has an enviable safety record. The fatality rate for this system for the period 1938 to 1948 was only 2.5 deaths per 100 million vehicle-miles.

The safety experience on the Chicago Outer Drive also is excellent, the rate in 1946 having been only 2.9 deaths per 100 million vehicle-miles.

The North Sacramento Freeway in California has had no fatalities during its first year of operation. Furthermore, accidents were reduced from 22 on the old route during the year preceding the opening of the Freeway, to 6 on the Freeway during its first year—a reduction of 73 percent.

The system of roads constructed in Arlington, Va., in connection with the Pentagon Building, comprises 17 miles of one-way through roads, 7.7 miles of one-way connecting ramps, and 2.3 miles of two-way local service roads. In the 6 years since its construction there have been only 1.5 deaths per 100 million vehicle-miles.

Table 4 summarizes highway fatality experience Nation-wide and on outstanding facilities. An excellent degree of highway safety is obtained with controlled-access design in which conflicts of all kinds—cross traffic, traffic entering along the roadsides, and pedestrian traffic—are materially reduced or eliminated.

TABLE 4.—*Summary of highway fatality experience*

Facility	Fatality rate (deaths per 100 million vehicle-miles)	Facility	Fatality rate (deaths per 100 million vehicle-miles)
National average:		Expressways—Continued	
1941	12.0	Metropolitan New York System, 1938–48	2.5
1948	8.1	California, Arroyo Seco, 1941–47	2.0
Divided highways:		Virginia, Pentagon Network, 1942–48	1.5
Connecticut, 1940–48	8.2	California, Sacramento Freeway, 1948	0
New Jersey, 1939–48	5.5	New Jersey Route 25, Newark, 1948	0
Expressways:			
Connecticut, 1940–48	3.2		
California, Riverside Drive, 1941–44	2.9		
Chicago Outer Drive, 1946	2.9		

Safety Design on Low-Volume Highways

Travel on secondary roads is customarily quite light compared with that on primary routes and main municipal streets. With less use, there is less justification for certain design refinements that are considered essential for more heavily traveled roadways. Secondary-road users, furthermore, are largely local residents familiar with the alinement and grade and presumably govern their driving accordingly.

Conditions often favor operation at moderate to high speeds, however. Hence the design [7] of these secondary-road improvements should make them safe for use under widely varying traffic, weather, and seasonal conditions. The design should approach or equal that of low-volume primary roads whenever costs are not substantially greater. Fund limitations and the low volumes to be served result in generally lower standards for secondary roads, but safety in design is obtained by provision of consistent and not widely variant cross-section, alinement, and profile features.

Need for Street Improvements Within Communities

Along major highway routes it is necessary to pass through or around numerous villages or cities ranging in population from several hundred upward to tens of thousands. In nearly every instance the safe operating speed of 30 to 60 miles per hour on rural sections of the route is in marked contrast with speeds of 10 to 30 miles per hour required for corresponding safe passage through these developed areas. Repeated attempts to control speeds by signs and other warning devices are frequently ineffective in producing the desired speed reduction as drivers enter a town. And lack of local engineering staffs and funds make it difficult to improve the town highways to standards consistent with the likely speeds. These conditions provide a fertile field for concentrated attack with numerous highway-safety measures. Highway design improvements of the following types generally are needed:

(1) A number and width of lanes for through traffic adequate to accommodate the vehicles anticipated during the recurring traffic peak periods.

(2) Extra-wide shoulder areas or equivalent to provide a clear space between the streams of through traffic and the local traffic.

(3) Off-street parking areas or separate parallel roadways to make unnecessary any stopping and parking on the shoulders or outer lanes of the through highway.

(4) Regulation and control of connections to roadside businesses to eliminate wide-open driveway areas along the highway—usually by reducing the number and length of driveway openings.

(5) Realistic coordination of design features with traffic-control devices, such as operation of traffic signals at intersections only during periods when justified by the traffic, pavement striping for proper lane use, control of both vehicles and pedestrians for crosswalk safety, practical speed zoning, and clear signing.

Similar problems are involved in the expansion and development of new urban areas. Material recently prepared by the National Com-

[7] See footnote 4.

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mittee for Traffic Safety [8] provides considerable assistance in enumeration of the design and operation features of street lay-outs in residential areas.

Application of Safe-Design Principles in Actual Construction Programs

The basic principles of safe highway design are briefly discussed herein and more fully described in the policies of the American Association of State Highway Officials. These need everyday application in the development of highway plans. The fact is clearly recognized in the findings of the highway study conducted in 1947 by Michigan highway agencies and interests under the sponsorship of the Michigan Good Roads Federation.

In this report, "Highway Needs in Michigan," issued early in 1948, design standards were established to govern the improvement of each of the functional classifications into which the State's total roadway mileage was tentatively grouped. These classifications are:

- Rural State trunk lines.
- Rural county roads
  - Primary county roads
  - Local county roads
- Municipal streets
  - Major streets, including State trunk-line routes
  - Local streets

The standards selected were based on the national standards, modified to take account of special conditions and needs existing in Michigan. The selection of design standards and highway types for the various traffic-volume ranges was made with full consideration of both traffic-capacity characteristics and traffic-safety experience.

In the preparation of the Michigan standards, which are reproduced in tables 5, 6, and 7, the degree of horizontal curvature, the superelevation of curves, and sight distances were considered to be functions of speed and are not separately enumerated.

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[8] Building Traffic Safety into Residential Developments, 1949, now being published by National Association of Home Builders, Urban Land Institute, in cooperation with the National Committee for Traffic Safety.

TABLE 5.—*Design standards for rural State trunk lines in Michigan*

HIGHWAYS

Average 24-hour traffic flow (number of vehicles)	Above 12,000	3,000–12,000 [1]	600–3,000		Up to 600
Commercial traffic	Heavy	Heavy	Heavy	Medium	Medium
All separated grades	Yes	No	No	No	No
Control of access	(2)	(3)	(4)	(4)	(4)
Number of lanes	[5] 4–6	[5] 4	2	2	2
Design speed (miles per hour)	70	70	70	60–70	60
Pavement type	(6)	(6)	(6)	(6)	(7)
Lane width (feet)	12	12	12	11	11
Maximum grade (percent)	3	3	3	4	4–6
Shoulder width (feet)	10	10	10	8	8
Right of way width (feet)	230	200	120	120	120

1 Trunk lines carrying 3,000–4,000 vehicles given special study.
2 Complete.
3 Partial or complete.
4 When located in developing areas.
5 Divided.
6 High.
7 Intermediate.

STRUCTURES

Design load H–20 S–16 Height over pavement 14 ft.
Clear width—curb to curb:
Less than 80 feet length Same as pavement width plus shoulders.
More than 80 feet length Same as pavement width plus 3 feet on each side.

TABLE 6.—*Design standards for county roads in Michigan*

ROADS

Road system	Average 24-hour traffic flow	Surface type	Surface width (feet)	Grade width (feet)	Alinement and gradient
Primary	Over 2,000	Concrete or similar	Same as State trunk-line standard.		
Do	100–2,000	Heavy blacktop	20	30	Safe.
Do	Under 100	Standard gravel	20	30	Do.
Local	Over 150	Light blacktop or surface-treated gravel	20	30	Do.
Do	50–150	Standard gravel	20	30	Do.
Do	Under 50	Minimum gravel	9	24	Do.
Platted streets in—					
Suburban areas		Gravel	18	30	
Resort areas		do	20	24	
Seasonal resort trail roads		No construction standard. These will be kept in proper condition by maintenance.			

BRIDGES AND SEPARATIONS

Primary			Local		
Average 24-hour traffic flow	Design load	Clear roadway width (feet)	Average 24-hour traffic flow	Design load	Clear roadway width (feet)
Over 2,000	H–20	(1)	Over 150	H–15	24
100–2,000	H–15	24	50–150	H–15	22
Under 100	H–15	24	Under 50	H–15	20

1 State trunk-line standards.

TABLE 7.—*Design standards for municipal streets in Michigan*

SECTION A. GENERAL FEATURES

Street class	Pavement widths, curb to curb (feet)	Surface type	Highway lighting	Traffic-control devices	Structures	
					Design load	Roadway width (feet)
A. Major streets	[1] 44–88	High	Yes	Yes	H–20	(2)
B. Local streets—						
Apartment-house districts (high population density).	36	do	No	No	H–15	36
Single-family residences (medium population density).	30	Intermediate	No	No	H–15	30
Country homes (low density).	20	do	No	No	H–15	24
Access to large industrial, warehouse or terminal areas.	44	High	Yes	Yes	H–20	44
Access to business areas and small industry.	40	Intermediate	Yes	Yes	H–20	40

[1] See Section B.
[2] Same as pavement width.

SECTION B. PAVEMENT WIDTHS FOR MAJOR STREETS

Average 24-hour traffic flow (vehicles per day)	Expressways (feet)	Intermediate areas (feet)	Business or industrial areas (no parking on street)		Heavy parking demand (parallel parking on street)	
			No left turns (feet)	20 percent turns (feet)	No left turns (feet)	20 percent turns (feet)
40,000–50,000	72					
30,000–40,000	48	88	88			
25,000–30,000	48	88	88			
20,000–25,000		66	66	88		
15,000–20,000		66	66	66	88	
12,000–15,000		44	44	66	88	88
9,000–12,000		44	44	44	66	88
7,500–9,000		44	44	44	66	66
6,000–7,500		44	44	44	44	66
Under 6,000		44	44	44	44	44

With reference to these tables, the Michigan report states:

"To provide the most efficient transportation service at the lowest cost, and to assure road users of the highest degree of safety, roadways must be designed and built to fit their varying uses.

"Standards governing the physical design of various types of roads and streets are a basic instrument in this process. They provide a means for planning orderly improvement programs, for calculating costs, and for translating technical knowledge into actual construction."

It cannot be stressed too greatly that the design standards adopted for current highway construction should be developed with safety as a primary consideration. As construction plans are prepared, road designs should be critically analyzed to see that all appropriate safety elements are provided. Omission of one or more seemingly minor details can materially affect the safety and traffic capacity of a road.

More attention must be given to methods of protecting the pedestrian, and to building turn-outs at bus stops so that vehicles can be stopped off the regular lanes of the roadway and thus not obstruct traffic.

Similarly on low-volume roads, attention should be given to shoulder surfacing at turn-outs where school busses and mail-delivery vehicles regularly stop. Some States now provide wide turn-outs along major truck routes so that during driver rest periods, large vehicles can be stopped well removed from through traffic.

Another safety feature gaining in application is the provision of an added upgrade lane on 2-lane highways with long grades.

Good Maintenance Necessary for Safety

Safety is aided by good road maintenance. Unexpected pavement and shoulder deficiences unrelieved by watchful maintenance practices, are hazardous, especially during night driving.

Maintenance preserves but does not increase the highway-plant capital investment. It is the round-the-clock task of maintenance crews to keep highways and streets in the best possible operating condition. Maintenance begins on the day when a new highway is opened for traffic, continues until the cost of upkeep is so prohibitive that the facility must be replaced, and resumes again on the new surface.

Largely hidden from the average motorist—whose yardstick is a smooth surface over which he can travel in safety and comfort at a reasonable speed—are the many and varied activities which produce a high standard of maintenance. Preceding the motorist and patrolling at his rear are crews trained to detect and promptly correct flaws and defects which, if neglected, would become the cause of accidents, damage to vehicles and inefficiency of traffic movement.

Day-by-day maintenance operations contribute materially to safe and efficient traffic movement by keeping shoulders firm, smooth, and flush with the pavement edges; by repairing surface holes, cracks, and corrugations; by repainting traffic stripes, sanding icy pavements, removing fallen rocks and trees, cleaning ditches and culverts, mowing weeds, and trimming brush and trees to insure adequate sight distances; by promptly replacing deteriorated and obsolete regulatory, warning, and direction signs with approved, uniform standard signs; and by painting guardrails, road obstacles, and buildings and keeping the public informed of road conditions, especially during storms and floods.

Major items are the constant inspection and upkeep of bridges, efficient operation of ferries, seasonal removal of snow, clearance of landslides, and repair of damage incident to severe floods. In addition to making repairs at points of potential danger, alertness is

necessary to detect deficiencies in roadway design that may create traffic hazards. There must be close cooperation between maintenance, traffic, and design engineers to assure the greatest safety and efficiency of road and street operation.

In many States the entire operation of signing and striping highways is a direct responsibility of the maintenance divisions. This work is of great importance to safety on all types of highways. And it is particularly important on lower-standard roads where it was not possible to build in the safety features.

Since the bulk of our highways are 2-lane pavements, maintenance of unmistakably clear center-line stripes is a major problem, and a never-ending one. On many rural and small-town roads the center-line stripe is a principal highway-safety element, often the only logical control device for safe operation. Its neglect thus becomes a major deficiency.

In areas where snow, ice, floods, and other weather conditions are apt to demand emergency maintenance, a coordinated plan, adequately financed, must be prepared in advance. Such a plan should include systematic analysis of weather forecasts and trends, training of personnel and arrangement for their prompt notification in time of emergency, conditioning and disposition of winter maintenance equipment according to probable need, and provision for periodic relief of workmen during emergency operations.

Two-way radio communication is often an efficient aid in maintenance, facilitating the prompt reporting of conditions that require the attention of the maintenance department. Two-way radio is especially helpful in initiating snow removal promptly when a storm begins.

Commercial radio stations can render a genuine safety service by broadcasting timely notices of dangerous highway conditions.

The cooperation of police officials in the enforcement of special traffic restrictions, which may be posted on special warning signs when snow or ice make travel hazardous, is also a factor contributing to safety during emergency operating conditions.

Since approximately half of the Nation's driving is done on city streets, good maintenance of urban roadways is of great importance. Traffic interference and some traffic hazards can be eliminated if maintenance operations in and near urban areas are scheduled during slack traffic hours or seasons.

Travel speeds in cities are normally lower where older, rougher pavements are in service. There is, however, need for good skid-resistant qualities on all city-street surfaces to permit the quick stops and changes in direction frequently required. Surfaces that become excessively slippery when wet deserve more attention than they have yet received. Furthermore, there is need of more widespread use,

on darker types of pavements, of light-colored surface dressings to improve visibility and safety at night.

In rural as well as in city areas, in addition to improving the skid-resistant and light-reflecting qualities of pavements, maintenance departments can contribute to safety by making other minor additions to the roadway. These include the construction of pedestrian fences and guardrails, flattening of slopes, removal or set-back of culvert headwalls, widening of shoulders, and widening of the traveled way, especially when it is less than 20 feet wide. Many of these improvements to the roadway have a substantial effect on the accident record. They are consequently appropriate for use wherever experience or a study of conditions indicates that they would improve the safety of travel.

The Minnesota State Highway Department has found through actual field load-bearing tests that many road foundations are weakened at least 50 percent by thawing action in the spring. Because of this weakening, roads which normally can carry substantial loads are likely to become seriously damaged and hazardous unless relieved of all vehicles of excessive weight. When roads are not protected from heavy vehicles during the spring breakup, they often close themselves to traffic by becoming unsafe and impassable.

All maintenance employees should be taught the importance of precautionary measures, not only for their own safety but also for the safety of the highway user. Special advance warning signs should be posted liberally to warn traffic when road conditions, or repairs, reconstruction or maintenance operations, require a change in normal driving. Temporary openings made in the pavement surface for underground facilities should always be protected with adequate warning devices that are clearly visible day or night.

Proper selection of maintenance personnel, adequate training in all maintenance duties including first-aid, continuity of service, and reasonable working hours eliminate many hazards created by inexperienced personnel and physical exhaustion. These factors are among the most important in obtaining maximum safety through maintenance operations.

THE OPERATION

Safe, free-flowing, convenient movement of vehicles and pedestrians is the most important measure of success in all vehicle and highway development. Human weaknesses do not permit the realization of completely accident-proof highway transportation, but our most serious operating losses, those of accidents and congestion, can be substantially reduced. This reduction can be achieved by wider application of proved techniques in traffic operation and control, and by adjustment of physical facilities to fit traffic requirements. The importance of seemingly small physical or control adjustments should not be overlooked.

Measures to promote safe and efficient traffic operation may be either restrictive or constructive. For economic and other reasons, some restrictive traffic-control measures—stop signs and traffic signals, for example—will always be required. When constructive measures are undertaken, such as added lanes for increased capacity, channelization, improved alinement, and grade separations, some of the old restrictions may be removed.

The utopian solution of the traffic safety problem would involve rebuilding all or nearly all of the existing streets and highways. For the most part, this is impossible from a financial and practical standpoint.

The only alternative is to apply those measures that will produce more efficiency, in terms of traffic capacity and safety, on present facilities. Falling in this category are such items as minor reconstruction or widening, improved and modernized traffic-control devices and methods, and the inauguration and enforcement of proper traffic restrictions such as one-way streets, prohibited parking, prohibited turning movements, and adequate bus-stop locations. As traffic continues to increase, this type of treatment will be more and more necessary.

The intelligent application of sound traffic-engineering principles to trouble spots often yields a sizable return in safety and increased mobility. This should be recognized, however: it is fundamentally wrong to attempt to correct abuses of a particular device or regulation that is not being adequately enforced, by substituting traffic-control devices and regulations designed for other purposes.

Need for Factual Data

The engineering approach to street and highway operating problems is a comparatively new specialization in the highway field, but it has the same need for basic facts as other highway-engineering efforts. The structural engineer must have fundamental data on working stresses of such materials as steel and concrete. The engineer dealing with operating and safety problems is equally dependent on data defining traffic volume, speed, and composition, and on knowledge of the characteristics of traffic movement under a wide range of conditions. Before a decision in the best interest of safe, efficient operation can be reached, the operating engineer must frequently acquire information on the origin and destination of travel, accident experience, causes of traffic delay, parking habits, use of mass transportation, pedestrian movement, driver reaction to design, operating speeds on various routes, or other similar data. By thorough study of the operation of an existing street or highway, the engineer derives valued facts for application to that facility and to other facilities.

Many basic problems are in dire need of objective study if the devices and techniques now at hand are to be most effectively used. The use of stop signs, for example, is in many instances governed only by rough evaluations or judgments as to need. The engineer will find substantiation of his decisions increasingly difficult without better knowledge of the psychological and operating facts of stop-sign control. The subject of driving speed has not been adequately explored, hence further researches in this field also are warranted by their importance to safely engineered highways.

The judgment of laymen and others understandably interested in traffic safety is often injected into considerations of traffic-operation problems. The engineer will, therefore, do well to pay especial attention to the integrity of his data and to devote his best ability to its application. This obligation is further emphasized by the great magnitude of the humanitarian and economic aspects of highway safety and the potential value of intelligent engineering solutions. Guesswork and uninformed opinion constitute a tremendous hindrance to the engineering attack, and can be dispelled only by appropriate factual information and experienced judgment, vigorously applied.

There is much need for evaluation of safety benefits accruing from highway and operating improvements. If the engineer has no factual knowledge of traffic conditions prior to improvement, he is in poor position to know the degree of effectiveness obtained. Before-and-after studies thus assume an important role in the fact-finding task.

As facts are obtained and applied to current problems, the engineer should not overlook the natural public interest in traffic and safety activities. Engineering solutions with much merit may fail in appli-

cation because of lack of public understanding and support. Proper education of the public is frequently an essential element in making new traffic-operation plans a success and in building public confidence in the factual approach employed by the engineer.

Engineering Analyis of Traffic Accidents

The details of traffic accidents are valuable to the engineer. Through careful study of accident experience in relation to engineering features, weaknesses in design and operating practices can be identified for both localized and general treatment. No other traffic facts will demonstrate street and highway inadequacies in such convincing terms.

In many jurisdictions, collection and analysis of accident data are primarily the function of an agency apart from the engineering unit responsible for street and highway development and operation. Under these circumstances, the engineer may find that the records are partly or wholly inaccessible for his everyday use, or that the data as compiled are useful solely to enforcement and motor-vehicle-administration officials.

The principal need of the engineer is not for mass statistical summarizations of accidents by days of the week or age, sex, and residence of the driver, interesting and informative though these relationships may be. His principal need is for selective analysis of roadway and traffic conditions on street and highway sections with high accident frequencies. This necessitates engineering investigations at accident sites to devise remedies in the fields of functional design, maintenance, control devices, regulation, and enforcement.

Practically equal in importance to investigations of high-accident locations is the appraisal of the entire street and highway mileage, section by section, in terms of accident frequency. The appraisal will be aided by the findings of special investigations at specific accident sites. Disseminated among officials directly concerned with administration, design, construction, maintenance, and operation, the results of the appraisal will facilitate intelligent direction of efforts to reduce accidents.

Engineering consideration of accident data is sufficiently important to warrant its introduction into every department or division responsible for traffic operation and control. Thus, new avenues of liaison must be opened between the engineer and the agency responsible for collection and analysis of accident facts so that more completeness in reporting and more precision as to location will be obtained. Report forms should be studied to determine whether additional engineering items are needed. Where deficiencies are found, the engineer should work out improvements in the form with the accident-records agency.

In his own investigation, the engineer will often find it desirable to

devise special methods and forms to record additional engineering data on roadway and traffic conditions.

Speed

Speed contributes to accidents primarily when excessive or "too fast for conditions" rather than when it is merely "high speed" or in excess of arbitrary numerical limit. When it is a contributing factor, the greater it is the greater the severity of the accidents.

A basic principle in efficient traffic operations is that motorists must be permitted to go to their destinations at a reasonably rapid rate consistent with safety. Plans for speed control should endeavor to eliminate unsafe speed without unduly restricting drivers at times and places where higher rates can be permitted with safety. Decisions must be made on the basis of facts: first, what is a dangerous speed? and second, what speeds are safe for various combinations of conditions? Speed limits are usually set for favorable conditions of weather, visibility, vehicle, and driver. Establishment of so-called safe limits does not, of course, relieve the driver of judgment as to further reductions under unfavorable conditions.

Unreasonably low limits cannot be properly enforced. The selection of realistic limits will induce respect and observance from most drivers and give more effective control of operating speeds. Posting statutory limits in areas where they apply is important, particularly if speed violations are frequent or if drivers may have reasonable doubt as to the applicable limit.

Because of the importance of speed as a factor both in safety and mobility, maximum use should be made of the factual approach in developing speed regulations and control measures. The practice of establishing a low limit and then permitting high tolerances in its enforcement is not sound and should be discontinued. The basic principles of article VI, Act V, Uniform Vehicle Code [9] are worthy of more widespread adoption. Article VI provides for the establishment of speed restrictions, and authorizes speed zoning and the setting of lower night limits.

Speed Zoning [10]

Speed zoning is the establishment of safe and reasonable speed limits for certain special zones or sections of rural highways and city streets where the general State-wide or local speed regulations do not fit road and traffic conditions. The special limits are determined by engineering studies.

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[9] The Uniform Vehicle Code can be obtained from the Superintendent of Documents, Washington 25, D. C. Price of Act V is 20 cents.

[10] Some of this discussion is based on "Speed Control," a report of the Joint Committee on Postwar Speed Control, December 1945. Copies are available from the National Safety Council, 20 North Wacker Drive, Chicago 6, Ill.

Experience has proved the safety value of properly employed speed zoning. It is of top importance that the speed posted in each zone be appropriate for the existing physical conditions and the character of the traffic expected. The pressures of local groups to impose unreasonable and unenforceable limits must be resisted. Some discrediting of the value of speed zoning as a useful control measure has occurred in instances where this caution has been ignored.

Properly applied, speed zoning aids the motorist in adjusting his speed to conditions, encourages general observance of all speed signs, and makes enforcement easier. It gives police a reasonable guide as to what is excessive speed under normal conditions of weather and traffic. Speed zoning also permits control of speed at locations with unusual conditions without unduly restricting drivers in other locations where higher speeds are normally permissible.

After a representative sample of speeds has been taken in the field, and roadside, roadway, and traffic conditions have been evaluated, a safe speed value should be determined and posted. In some cases this may involve raising instead of lowering the existing limits. Special speed-control signals and signal systems designed to restrict speed within a prescribed maximum, are useful accessories to speed zoning in localized areas and under some conditions. But arbitrary installation of conventional traffic signals with the hope of reducing speed frequently gives ineffective results, and may even increase accident frequency.

Motorists tend to become speed conscious and drive closer to the appropriate speed when zoning is correctly applied. When speed zoning is supported by good enforcement, it is effective in reducing the frequency and severity of accidents on dangerous sections of streets and highways.

The minimum requirements in any determination of locations and speeds for speed zones are:

1. Study of the physical characteristics of the roadway and the adjacent roadside development.

2. Representative field checks of prevailing motor-vehicle speeds and traffic volumes.

3. Studies of accident experience and vehicular and pedestrian conflicts.

4. Checkbacks to see whether limits are appropriate.

The essentials to success in speed zoning are:

1. Adequate speed-zone signs, conspicuously located.

2. Numerical limits based upon an engineering study for normal traffic and good weather conditions, with no unreasonably low limits.

3. Repetitive signing for emphasis near zone entrance and consistently spaced posting thereafter.

4. Advance and follow-up publicity to acquaint the public with speed zoning.
5. Training of officers in proper methods of enforcement.
6. Reasonable enforcement of the zoned speed limits.
7. Adequate penalties imposed by the courts for violations.
8. Periodic checkbacks or engineering studies to review conditions.

Zoning of night limits.—The zoning of city streets and highways with nighttime speed limits 5 to 10 miles per hour lower than the daytime limits has been found effective in reducing night accidents.

Zoning of transition areas.—The transition sections between open rural highway conditions and the centers of small communities, and sections through the suburban districts of larger cities, are well-known hotbeds for traffic accidents. The driver's failure to adjust his driving speed to the changing roadway and roadside features so typical of these areas, undoubtedly contributes to the adverse accident record. Adequate posting of graduated speed zones consistent with the environment will assist in controlling speed through these critical sections.

Safe speeds on curves.—Experience has shown that when safe speeds on curves are determined by careful field study, the speed indication posted just below the curve-symbol signs helps motorists considerably in adjusting their speeds to normal conditions, increases the comfort of driving, and reduces the number and severity of accidents on curves.

Information program on speed control.—A public information program is an important element in successful speed control. Its purpose is to acquaint the public with the meaning of speed signs and the necessity for adjusting speed to conditions.

Effect of Restrictions on Vehicle Sizes and Weights

Compared with passenger cars, large, heavy commercial vehicles occupy more roadway space and frequently travel at much lower speeds on ascending grades. This creates hazards due to the difficulty of passing and the danger of serious collisions, particularly on long, steep grades.

Because of the need for vehicles of all sizes and weights to use the same roadways, uniformity in the size-and-weight restrictions applying to commercial vehicles is of prime importance. It is felt that the adoption by all States of the uniform size and weight limitations [11] agreed upon by the American Association of State Highway Officials, and ratified by a majority of the States, would contribute substantially to the solution of this problem.

[11] The Policy Concerning Maximum Dimensions, Weights and Speeds of Motor Vehicles to be Operated over the Highways of the United States, approved April 1, 1946, can be obtained from the American Association of State Highway Officials, 1220 National Press Building, Washington 4, D. C.

Skillful operation can compensate in part for the hazards inherent in commercial vehicles of unusual size and weight. It has been proved that careful selection of drivers, safety programs, and the training and retraining of drivers of heavy equipment are distinctly helpful in reducing commercial-vehicle accidents.

Influence of Traffic and Roadway Conditions on Safe Vehicle Operation

Road defects, inadequate or faulty road design, and lack of suitable control devices often restrict traffic flow and beset drivers with more or less constant accident hazards. New design and construction provide opportunity to build safety into the highway and at the same time to increase its capacity to accommodate a maximum number of vehicles at reasonable speeds with a minimum of interferences.

Because they contribute to accidents, some features should be eliminated or their hazard reduced to a practical minimum. These hazardous features are:

1. Inadequate widths of pavements, traffic lanes, shoulders, and bridges.
2. Improper superelevation of pavement and shoulders and high crown.
3. Rough and slippery pavement surfaces.
4. Lack of hard, smooth, wide shoulders flush with pavement edge.
5. Lack of proper drainage facilities to keep water from running across or ponding on the pavement.
6. Steep side slopes, deep ditches, culvert headwalls, and other roadside structures that obstruct or restrict the free and orderly flow of traffic.
7. Excessive curvature, awkward or unexpected transitions in alinement, and long steep grades.
8. Restricted sight distances, and poor visibility for day and night driving.
9. Highway and railroad crossings at grade.
10. Lack of needed channelization.
11. Lack of special provisions for mass carriers.
12. Lack of pedestrian accommodations and control.
13. Too-small, poorly located, and nonuniform signs, signals, and other traffic-control devices.
14. Curb and angle parking, and inadequate facilities for off-street parking.

Building safety into highways will eliminate many accidents. However, temporary hazards created by weather—wet or icy roads, fog, and storms—also may lead to high frequency and severity of accidents for their duration. While some of these conditions can be made less hazardous by special treatment such as sanding icy roads,

a major responsibility for avoiding accidents is quite definitely with drivers and pedestrians. This fact underlines the importance of better public education regarding temporary hazards.

Supplementing the precautions of individual drivers and pedestrians, special road-maintenance methods and special vehicle equipment will always be necessary to combat temporary hazards due to weather, particularly the hazards of winter in the northern States. With increasing use of vehicles in all kinds of weather, encouraged largely by improvements for comfort, the hazards of weather are now encountered by larger numbers of drivers. Thus the need is greater than ever before for making full use of improved road-maintenance techniques and improved vehicle-safety equipment.

In the interest of maximum safety under winter conditions, ice and snow should be completely removed from the roadway. Since bare-pavement maintenance is not posible at all times and locations, vehicles that must operate on snow and ice ought to be equipped with tire chains, sanders, or other traction or skid-protection devices. Engineering studies [12] have demonstrated their value in stopping and controlling vehicles on ice- or snow-covered pavements.

Of equal importance, devices on the vehicle, such as windshield wipers, defrosters, frost shields, and the best of lighting equipment, should be in good working order to assure the maximum possible visibility.

Traffic-Control Devices and Techniques

National uniformity is essential in the design and location of guide, regulatory, and warning signs, signals, center lines, no-passing-zone and other pavement markings, curb and obstruction markings, and other traffic-control devices. Uniformity promotes the maximum observance of these aids to traffic control, thus minimizing confusion and contributing to safety.

Official standards for traffic-control devices, and techniques for their use, have been established by the Manual on Uniform Traffic Control Devices,[13] prepared by a Joint Committee of the American Association of State Highway Officials, the Institute of Traffic Engineers, and the National Conference on Street and Highway Safety. The latter has been succeeded by the National Committee on Traffic Laws and Ordinances.

The use of traffic-control devices should be based on need as established by factual studies, and not on guesses or opinions. The misapplication of traffic-control measures to offset weaknesses in enforce-

[12] Reports of the National Safety Council's Committee on Winter Driving Hazards are available from the National Safety Council, 20 North Wacker Drive, Chicago 6, Ill.

[13] The Manual on Uniform Traffic Control Devices, revised and approved as an American Standard in 1948, is for sale by the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C. Price 50 cents.

ment, or the unnecessary use of signs, signals, or markings, results in disregard for them and in many cases contributes to accidents.

Standard pavement markings and properly designed islands are valuable aids to driving and to pedestrian protection. The use of standard markings is important, especially to indicate zones where overtaking and passing maneuvers are hazardous.

On main rural roads, substantial reductions in night accidents have been achieved through the use of highway delineators. These are small retrodirective reflectors mounted on standards at properly spaced intervals along the roadside.

All warning signs, stop signs, and important directional and informational signs should be reflectorized or illuminated to make them visible at night. Oversize signs are very effective when employed selectively at complex intersections, on high-speed roadways, and at other difficult or hazardous locations.

An increasing amount of interference and confusion is being created by colored reflectorized or illuminated advertising signs near traffic signs and signals. These distractions should always be controlled to insure adequate target value and effectiveness for all official traffic-control signs and signals.

Proper maintenance of traffic-control devices is essential. Poorly maintained signs, signals, markings, and islands quickly become ineffective and fail to command full respect and observance.

All obsolete, damaged, or worn-out traffic-control devices should be replaced by standard devices as rapidly as possible. A plan of progressive replacement of nonstandard or worn-out devices is recommended. This will lead to full conversion to national standards within a reasonable time.

Highway-Railroad Grade-Crossing Protection

The only positive method of preventing collisions at highway-railroad crossings, as at other traffic intersections at grade, is by separation of these grades. Principal railroad grade crossings of major traffic thoroughfares should be separated in the order of their relative hazards and economic benefits.

Where it is not possible to separate grades at major crossings, suitable standard-type barriers should be provided. At less important crossings, standard-type signals and signs should be installed.

Adequate night illumination of grade crossings is desirable. If drivers have a better view of the sides of trains—unlighted freight cars in particular—they are less likely to try to drive onto crossings once the locomotive has passed.

No matter what type of grade-crossing protection equipment is installed, it needs police support in equal measure with other traffic-control devices.

In all instances where actual grade separation is effected, the old crossing should be completely closed. Along railroad lines that have been abandoned highway grade-crossing signs and other protective devices previously employed should be removed to avoid giving false indications to motorists. The ability of the railroad companies to cooperate in this action would be facilitated by enactment of the necessary legislation in those jurisdictions where such removals are now restrained by law.

In the interest of early elimination of grade-crossing hazards, it is important that the costs of this work be divided on the basis of relative benefits to railway and highway interests. Present State and local laws are not entirely modern in this respect. The Federal Aid Highway Act of 1944 has workable provisions relating to this subject of cost division.

School busses, passenger-carrying common carriers, and certain other commercial vehicles are usually required by law or company rules, or both, to make a complete stop at all railroad grade crossings. When these vehicles stop in a traffic lane, numerous rear-end collisions occur because following vehicles fail to stop in time. To abate these mishaps, the traffic engineer should see that proper advance-warning devices are installed to alert drivers to this danger.

Pedestrian Control

The problem of pedestrian accidents is a most serious one, as indicated by the following statistics:

1. In cities, one-half to three-fourths of all persons killed in traffic accidents are pedestrians.

2. In rural areas, approximately one-sixth of the traffic victims are pedestrians.

3. Pedestrian deaths in city and rural areas combined account for nearly one-third of the Nation's traffic accident toll.

The following measures have been found successful in reducing pedestrian accidents:

1. Adequate street lighting (two-thirds of urban pedestrian fatalities occur at night when travel is about one-third of the 24-hour total).
2. Physical aids for pedestrian protection.
   a. Pedestrian refuge and loading islands.
   b. Channelization of vehicle paths.
   c. Adequately marked crosswalks.
   d. Overpasses and underpasses.
   e. Sidewalks in rural areas.
   f. Pedestrian barriers.
3. Properly operated traffic signals when warranted.
4. Uniform legislation to protect, regulate, and control pedestrians.
5. Police protection when warranted.

6. Properly located and fenced off-street recreation areas for children.

7. Special protection for school children.

a. Elimination of parking in the immediate vicinity of school property and crossings.

b. School warning signs.

c. Proper operation and supervision of school busses.

d. Protection through school safety patrols, adult guards, or special police.

Since at least two-thirds of all pedestrian fatalities are attributed to pedestrian carelessness, physical deficiencies, and lack of understanding of traffic and driver problems, the application of engineering treatments cannot in themselves entirely remedy the pedestrian phase of the accident problem. They must be supplemented by an extensive year-round adult and child traffic-education program, and understanding but firm enforcement.

One-Way Streets

Much greater use of the one-way-street principle is warranted and is now being made. But thorough engineering studies of traffic needs and available facilities should precede the establishment of one-way streets so that where this operation is advisable, the greatest advantages may be realized. Experience has shown that if one-way-street regulations are wisely applied, accidents, running time, and traffic congestion generally will be reduced.

The capacity of a street is increased markedly when it is operated one-way rather than two-way, largely because of the reduction in conflicts at intersections. The 16 potential conflicts at the intersection of 2 typical two-way streets are reduced to 7 conflicts at the intersection of a two-way street with a one-way street, and to 4 conflicts at the intersection of 2 one-way streets.

Other hazards due to speed variations, parking, and signal-timing difficulties are also alleviated. Pedestrian safety is enhanced by the fact that a pedestrian has to look for approaching traffic in but one direction when crossing a one-way street. Figure 8 presents some of the significant advantages in graphic form.

In addition to its general application, the one-way principle may often be used on streets that are too narrow to permit free two-way movement without unreasonable restrictions on stopping or parking.

Segregation of Vehicle Types by Lanes and Roadways

On streets and highways, particularly high-speed thoroughfares that must accommodate slow trucks as well as fast passenger vehicles, enforcement of the customary regulation providing that slow vehicles shall keep to the right will decrease congestion and increase capacity

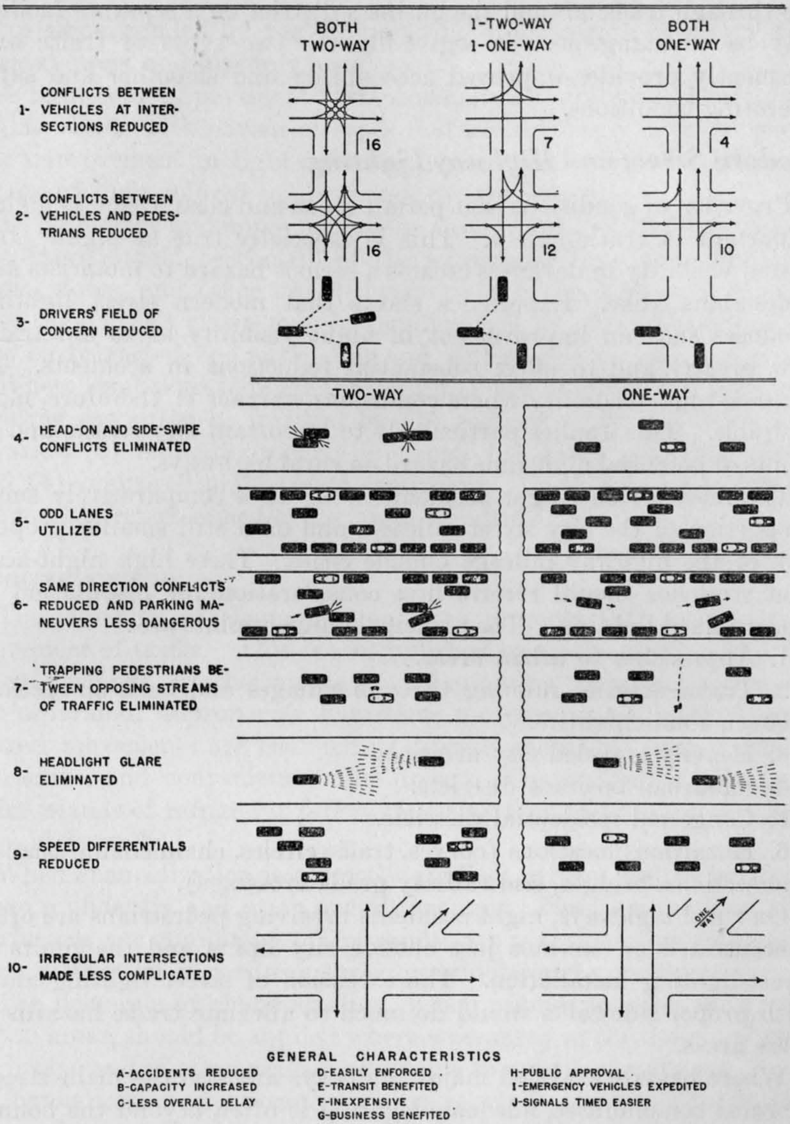

FIGURE 8.—Some operating and safety advantages of one-way streets.

and safety. Additional lanes for heavy vehicles on ascending grades are also especially helpful.

Street traffic congestion is often caused by mixture of a high percentage of trucks with passenger cars in the same traffic stream. The segregation of truck traffic on separate routes or in separate lanes will oftentimes result in safety and other operating benefits to truck and passenger vehicles alike.

Streets in central business areas are frequently congested because of the conflict between local traffic and through traffic. Bypassing

the through traffic around the business district on a separate facility may be advantageous. It segregates the two types of traffic and frequently provides improved accessibility and smoother and safer operating conditions.

Modern Street and Highway Lighting

Provision of conditions that permit quick and clear vision is highly important in traffic safety. This is especially true at night. Impaired visibility in darkness creates a serious hazard to motorists and pedestrians alike. Experience shows that modern street lighting produces such an improvement in night visibility as to aid traffic flow greatly and to effect substantial reductions in accidents. To increase night visibility where conditions warrant is, therefore, most desirable. This applies particularly to important city streets and to points of potential nighttime hazard on rural highways.

The most serious night accidents occur on a comparatively small proportion of the city street mileage, and on a still smaller proportion of the highway mileage outside cities. These high night-accident stretches should receive first consideration for installation of modern fixed lighting. The principal danger points are:

1. Approaches to urban areas.
2. Traffic arteries running through villages and built-up sections between municipalities.
3. Heavily traveled city arterials.
4. Suburban business districts.
5. Congested residential districts.
6. Hazardous locations (curves, traffic circles, channelizing islands, intersections, bridges, and railway grade crossings).

On rural highways, night accidents involving pedestrians are often concentrated on sections just outside city limits and the limits of street-lighting installation. The extension of street lighting along with proper sidewalks would do much to alleviate traffic hazards in these areas.

Where heavily traveled major highways are also the main streets of rural communities, adequate lighting is often beyond the bounds of the local budget. Some States are aiding in the modernization of lighting on these facilities in recognition of the safety needs of through traffic.

In many instances, existing lighting systems can be modernized at relatively small conversion costs by the use of fixtures that direct the light more efficiently onto the pavement. In this way as well as by the installation of entirely new equipment, States and communities can obtain satisfactory illumination levels approaching or equalling

those recommended by the Illuminating Engineering Society [14] for various street and highway conditions.

A light-colored pavement surface enhances visibility and safety at night. Even with pavement types that are relatively dark, substantial improvement in light-reflecting characteristics can be achieved by use of light-colored top dressings or aggregates.

To obtain the maximum usefulness from street and highway lighting, there should be control of the extraneous light from flashing signs, stores, and other establishments along the highway. Otherwise the driver's vision may be handicapped by glare, his attention may be distracted, and misleading and confusing situations may arise.

Where conditions indicate the need, the cost of street and highway lighting can often be justified by (1) reduced traffic fatalities and injuries, (2) reduced property damages, (3) lower insurance rates, and (4) improved night-travel conditions. Good lighting is one of the most effective remedies for night accidents.

Channelization

The objective of channelization is to promote safe and orderly movement of traffic. This is accomplished by means of islands, divisional curbings, or other means so that opposing movements of traffic are separated, improper or hazardous movements are blocked, and correct movements are confined to definite paths that seem natural, attractive, and convenient to the driver. Channelization also provides islands of refuge for pedestrians, usually midstream in the flow of vehicle traffic.

When channelization is correctly applied, drivers and pedestrians move confidently and in an orderly manner. Needless conflicts and confusions are eliminated. The results are safe operation and optimum utilization of roadway space by vehicles and pedestrians.

The principle of channelization, which applies to both rural and urban areas, should be applied where warranted in the design of new highways and is often readily adaptable to existing roadways.

Channelization treatment must be carefully designed to fit the circumstances of each case. Improperly applied or with inadequate treatment of the approach ends of the islands involved, it may result in awkward or even hazardous traffic movements, and in delays and conflicts. Preliminary tests of proposed treatments are often desirable. Proper lighting or reflectorization to identify the channelized areas should always receive thorough consideration.

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[14] "American Standard Practice for Street and Highway Lighting" approved by American Standards Association, September 30, 1947, is available from the Illuminating Engineering Society, 51 Madison Avenue, New York 10, N. Y. Price 50 cents.

Intersection Control

It is at the intersection of two or more streets or highways at grade that the greatest opportunity for traffic conflict exists. Since grade intersections are so essential in the distribution of traffic, intersection conflicts are consequently of the utmost concern to the engineer.

The degree of hazard at grade intersections usually varies with the direction and volume of traffic flows, both vehicular and pedestrian, the sight distance on the approaches and through each quadrant of the intersection, the prevailing approach speeds, the geometric lay-out, the methods of traffic control, the types of regulatory or warning devices employed, and other factors. The methods of control and the types of devices used are often the only ones that can readily be modified, and hence are of vital importance to the engineer from the standpoint of efficiency and safety of operation.

Warrants for various types of intersection controls have been particularly emphasized in the 1948 Manual on Uniform Traffic Control Devices. Before selecting intersection controls, the engineer should become thoroughly informed of traffic and roadway features and the accident history at the intersection. Condition and collision diagrams are especially helpful in the preliminary study and often suggest particular ways in which an intersection can be made to function more safely and smoothly. The most effective control or treatment is frequently the one causing the least restriction in normal traffic operation, consistent with the needs of safety.

The public and some engineers have a tendency to rely on the conventional traffic-control signal for solution of all intersection problems. Experience has demonstrated that signal installations inappropriately selected or adapted to conditions may increase rather than reduce accident frequency. Two-way or even four-way stop-sign control has been applied successfully at locations where public demand strongly favored signalized control. In advance of a final decision on treatment, it is consequently incumbent on the engineer to examine in some detail the various physical and operating characteristics of each problem intersection and the likely effect of various possible controls or physical adjustments. This type of approach makes it much more likely that intersection-control problems will have the benefit of the full range of remedies available through engineering and operating improvements.

Through-Street Systems

A system of streets selected and adapted for the preferential handling of through or continuous traffic can do much to improve the flow of main traffic streams and unburden less adequate streets. Safety and efficiency are advantages gained by the traffic handled in this way.

Control methods and minor physical improvements can be directed toward accommodation of the main traffic flows. Relieved of through traffic, the local streets have less noise, hazard, and congestion, and pedestrian movements particularly are more safely handled.

The provisions of Act V, Uniform Vehicle Code, and of the Model Traffic Ordinance contemplate definite protection from side-street traffic by the use of stop signs, or an effective equivalent, at all intersections along an officially designated through street.

Short sections of through street are often undesirable because they acclimate the driver to a sense of security that applies only to a fraction of his travel.

Oftentimes paved one-way streets become successful parts of an effective through-street system. This is one more means of using existing streets more effectively and safely to handle the increasing volumes of present-day traffic.[15]

Unbalanced-Lane Flow

In the hours of peak traffic there is normally a substantial predominance in the volume of vehicles moving in one direction, particularly on arterial routes connecting with central city areas. In some cases where multilane facilities are available, it is possible by applying the unbalanced-flow regulation to reserve a greater roadway width for the dominant movement. Under this plan, one or more of the inner lanes normally used for travel in the opposite direction, assists in handling the heavy-direction movement, and the lesser number of lanes remains for the lighter flow.

This method of handling peak traffic loads can be employed only when relatively wide thoroughfares are available. Effective police supervision and proper use of markings, signs, and other devices is necessary to insure against confusion to motorists. Signal units are sometimes mounted overhead at regular intervals for positive indication of the lanes available for travel in each direction. Safety of movement during the hours of light traffic is increased by creating a neutral zone in one of the central lanes by displaying red signal indications in both directions.

Relation of Parking Provisions to Safety

Until such time as adequate offstreet facilities can be provided for vehicle parking and for loading and unloading, the use of curb space will continue on many streets, even in downtown areas. It is emphasized, however, that where parking demand is heavy, the problem cannot be solved at the curb. Ultimately along roadways in urban shopping centers and on important urban arterial routes, most of the

[15] "Making Better Use of Today's Streets," United States Chamber of Commerce, Washington 6, D. C.

curb space will be used solely for vehicle movement and necessary loading and unloading. Where permitted, curb parking and loading should be so regulated as to cause a minimum of hazard and interference with the movement of vehicles. Making the best use of curb space obviously reduces the amount of offstreet parking needed.

Curb parking seriously decreases the capacity of streets for moving traffic, and tends to produce congestion and accidents. But where

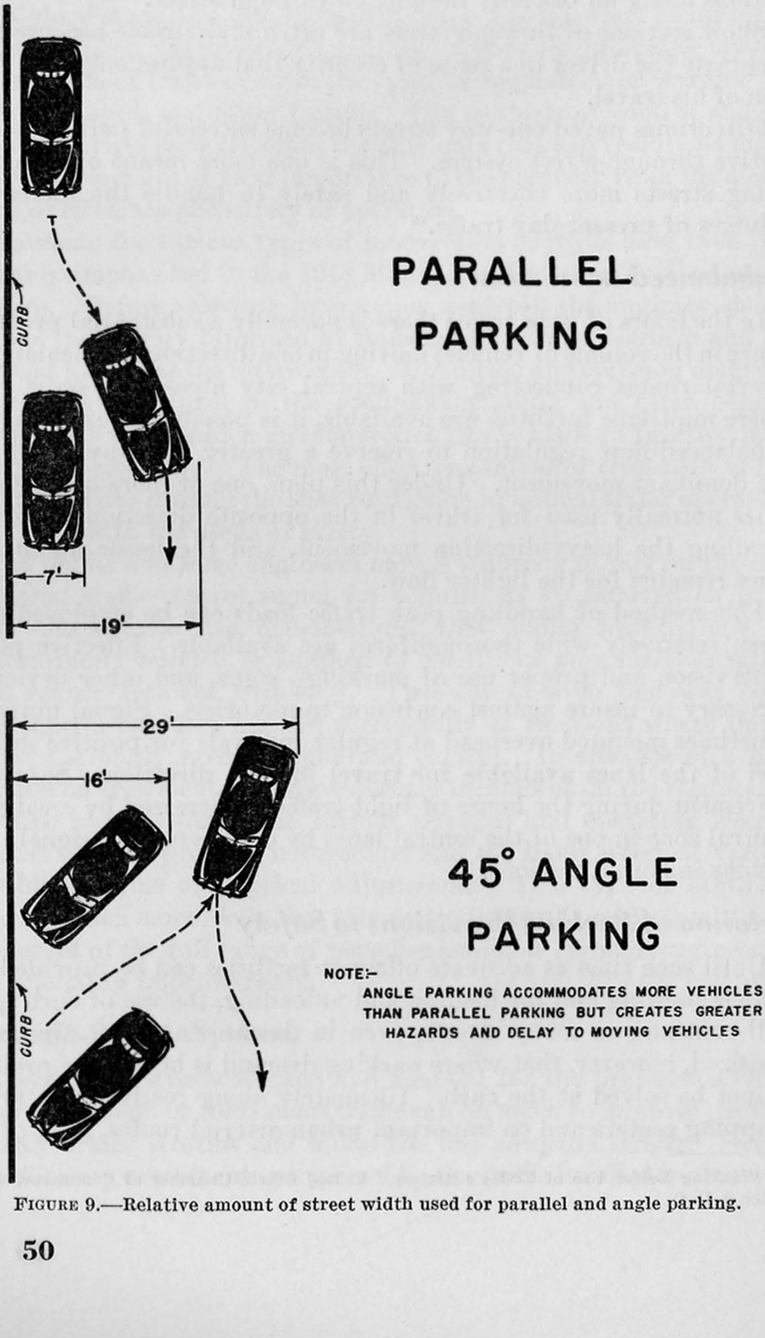

FIGURE 9.—Relative amount of street width used for parallel and angle parking.

parking is allowed on densely traveled streets, cars should be parked parallel to the curb. Angle parking accommodates more cars along a given length of curb, but causes much more delay and hazard, and hence is not recommended. Figure 9 shows the relative amounts of street width required for parallel and angle parking.

Parking regulations governing the use of curb space should comply with the provisions of Act V, Uniform Vehicle Code, and of the Model Traffic Ordinance, particularly with respect to the clearance distances from intersections. Parking too close to an intersection or crosswalk hampers clear visibility and often contributes to pedestrian and right-angle-collision accidents.

More prohibition of peak-hour parking on arterial routes is needed in most cities.

The traffic engineer will find it increasingly necessary to solicit the cooperation of merchants and businessmen and to inform them adequately in working out solutions of the parking problem. Much helpful literature [16] is available on the subject.

The eventual solution of the parking problem in congested areas depends on the provision of off-street parking and loading facilities, including surface parking lots or multilevel garages of either the enclosed or open-air type. As these facilities are planned, it should be kept in mind that location, design, and control of entrances and exits greatly affect the safety of their operation.

Protection of the Roadside

The safety and traffic serviceability of hundreds of miles of modern, costly highway have been severely handicapped by the rapid development of commercial and recreational establishments at the roadside. Even a single business place on a rural road creates new patterns of traffic in its neighborhood. If its traffic connections are not properly integrated with the highway lay-out, it creates serious hazards. A highway fringed with these places may easily lose a large part of its capacity and utility as a transportation artery.

It should be required that entrance driveways be correctly placed, not too wide, and not located within a short-sight-distance area. Wherever possible, property owners should be required to provide off-the-road parking facilities.

Transit-Vehicle Stops

The location of bus stops on ordinary city streets deserves careful consideration. They should be long enough not only to accommodate

[16] "Parking Manual," American Automobile Association, Washington 6, D. C. "Parking" and "Zoning Applied to Parking," Eno Foundation for Highway Traffic Control, Saugatuck, Conn. "Parking for Smaller Cities," Indiana Retailers Association, 808 State Life Building, Indianapolis, Ind. "Factual Guide on Automobile Parking for the Smaller Cities," Public Roads Administration, Washington 25, D. C. "Solutions to Local Parking Problems," Automotive Safety Foundation, Washington 6, D. C.

the maximum number of busses that stop at any one time but also to provide whatever added space may be required to turn into or out of them. When adequate space is provided, busses should be required by local authorities to stop parallel to and at the curb. Other vehicles should be prohibited from stopping in bus stops. Segregation of bus loading points according to routes, and lengthening of bus-stop zones by additional parking prohibition, have been found helpful during peak-hour-traffic periods in some cities.

With the development of expressways, proper facilities need to be provided for transit-vehicle stops. The location and design of these facilities should protect transit riders from traffic hazards and other highway users from transit-vehicle operations. A longer-than-normal spacing between bus stops is often feasible on expressways and makes for smoother operation of all traffic.

Truck-Loading Zones and Terminals

Safety in truck transportation, since it involves large heavy vehicles, can be realized only when adequate facilities are available for their terminal accommodation. In the main this function is performed by loading zones specifically designated at the curb for commercial use, by loading bays or recesses provided as an adjunct to the establishment served and immediately adjoining the street or in an alley, and by offstreet warehouse installations. The intensive use of land area in the downtown core of the larger cities will probably force retention of curb loading and unloading for some time.

Prohibition of peak-hour deliveries and enforced night deliveries naturally require some adjustment in the working hours of truckers and of crews at the establishments being served, and are generally opposed on this account. Nevertheless, increasing restriction on the hours for delivery and pick up seems certain. Night deliveries will have to be more general until adequate loading recesses and terminal accommodations can be provided. If urban congestion and safety problems are to be held within reasonable limits, the engineer must plan for and work toward the provision of efficiently designed off-street loading bays and terminals for modern street and highway transport.

THE VEHICLE

General Safety Policy

Safe operation has always been a major objective of the motor-vehicle designer. Long before traffic accidents became a matter of national concern, the automotive industry in its earliest days began engineering efforts to minimize failures which cause accidents and to make it easier for the driver to operate safely even when his own lapses, or the carelessness of others, confront him with hazardous situations. This engineering pressure on designs for safety has continued through the years and will continue in the years to come.

Emphasis on safety in design has produced vehicles which can be operated safely without unreasonable effort by drivers who exercise normal care. This is being demonstrated constantly in the billion miles these vehicles travel daily. The great bulk of this mileage is driven without accidents. But the small part of the total operation which results in accidents produces startling totals of death, injury, and property damage. Automotive engineering has a role to play in the reduction of these tragic losses. Its past contributions to safety are assurance that it may be counted upon in future safety efforts.

Dependability of the Modern Automobile

Certain design developments are properly regarded as milestones in the history of automotive safety engineering. The stress that has been placed on these more dramatic advances, however, has tended to obscure the over-all contribution which the dependability of the modern automobile makes to safety. This reliability is the product of painstaking, safety-conscious engineering applied to a myriad of design details.

In one part, reliability may result from expert selection of a material or close control of its heat treatment. In another part it may be the product of its geometrical design and the way it is machined, both combining to prevent failure from fatigue. In still other instances, reliability may be achieved through developmental work which creates a mechanism capable of operating unfailingly through thousands or millions of cycles. Or it may result from such a detail as a seal on a bearing which excludes dirt and thus prevents wear that would lead to failure. In the aggregate such unspectacular details

combine to produce a vehicle that is reliable, safe, and responsive to the driver's control.

Résumé of Principal Safety Developments

Among the major milestones in automotive safety engineering are the self-starter, four-wheel brakes, safety glass, all-steel bodies, and sealed-beam headlighting. In addition, there has been major progress safetywise in tire life and reliability; in reduction of noise and vibration—causes of driver fatigue; in better handling and steering characteristics; in the simplification of the mechanics of driving, permitting the driver to devote his attention more completely to safe operation; and in other features such as riding comfort and lowered centers of gravity.

Brakes.—Brakes have been the subject of continuous development. The materials of the braking elements and the means for operating the brakes, involving power assistance or operation on heavy vehicles, are some of the more important examples of this work. These developments, combined with brakes on all wheels, have made it possible to provide braking means capable of utilizing the full potential adhesion of the tire to the road. Use of this full potential must be tempered by such considerations as the wide variations of the condition of the road surfaces and the differences in loaded and unloaded vehicle weights. This in part is a matter of design to guard against too much braking capacity on the steered wheels and of skill on the part of the driver to avoid locking the wheels.

It should be emphasized that retaining steering control of the vehicle is at least equal in importance to quick deceleration. To insure a practical balance between these two requirements in the interest of safety, there is a limitation on the braking power provided as well as used by the driver.

The problems of providing maximum brake capacity increase with the weight of the vehicle, particularly in heavy trucks where the loaded weight may be twice the unloaded weight. Power operation or assistance is an invaluable aid in attaining the desired braking ability but still leaves a gap between the braking ability of heavy and light vehicles. Some progress has been made since the war in narrowing this gap as the result of improvements in power brakes, including a reduction in lag time.

The necessity for passenger cars and commercial vehicles to operate in the same traffic stream creates a problem which at present can be resolved only by recognition of this difference in braking ability by the operators of all vehicles. Study of this problem is the subject of research by the Public Roads Administration and of cooperative consideration through industry committees.

Safety glazing materials.—The universal use of safety glass in windshields is an illustration of the persistent interest of automotive engineers in safe design. The windshield was one of the first items added to improve the comfort of the user. When glass windshields were first proposed, engineers hesitated to use them because of the danger of serious injury to occupants of the car from jagged pieces of broken glass. After many attempts were made to reduce this danger, the idea of using a piece of transparent plastic cemented between two pieces of thin glass was conceived, thus eliminating the small flying pieces of broken glass and the large jagged pieces previously the cause of so many serious injuries. During its development safety glass has been made so resistant to breakage that it is now being criticized because of its strength, for in many accidents passengers suffer skull fractures instead of cuts. Serious efforts are currently being made to reduce impacts by improving mountings for windshield glazing.

Vehicle bodies.—A great contribution to safety, vision, comfort, and appearance is found in the all-steel body structure of today. The modern conception of the closed body as an enclosure for the passengers providing the maximum safety and protection from the elements, is the result of years of intensive development in treating the body as an integral part of the whole structure. Design stress is being placed on broadening the driver's range of vision without sacrificing structural strength necessary for support of roof, doors, and windshield. Some of the results of current engineering emphasis on this problem are apparent in the slimmer front corner posts and center door pillars of the new models. In the interests of better riding qualities, the seats have been moved forward.

Removing projections, such as hinges and external lamps, has reduced annoying wind noises, and the general smoothing of contours at the side and frontal portions of the car has improved appearance as well as economy of operation.

The required height and spacing of headlamps for proper road illumination and width-definition of the car at night, control the frontal height of fenders. The hood height at the front is, in most cases, controlled by the required radiator-fan combination. Recognizing criticisms of hood height, manufacturers have reduced both the height and the length of hoods in the new models to improve vision directly in front of the car.

Variations in the eye heights of seated drivers have always complicated the engineer's efforts to improve the range of driver vision. In general, the practice is to design for the average driver and to try to meet the requirements of drivers who depart substantially from the average by means of seat adjustment. This problem is the subject of continuing engineering attention.

In the last decade or so another vision problem has been presented by the public demand for front seats wide enough to accommodate three adults. Meeting this demand has tended to move the driver farther to the left and hence more nearly in back of the left windshield post. The reduced size of this post and the increased glass areas in postwar models are results of work to solve this and other vision problems.

Interferences with vision caused by side-mounted spotlights and outside mirrors have also been recognized, and steps are under way to modify mountings, for no accessory should be designed or mounted in such a way as to obstruct vision.

Although progress has been made in improving interior appointments, efforts to minimize hazards, such as the accidental opening of doors, are continuing. Safety improvements are also being made in the design and convenience of controls and operating handles.

Headlighting.—Operation of the vehicle after dark on unlighted roads under the variety of conditions and distractions apt to be encountered, including the range in weather, imposes a tremendous burden upon the headlamps to provide visibility distances in excess of stopping distances. Extensive test data substantiated by experience prove that any distribution of light from headlamps that provides adequate visibility when no cars are approaching, will direct intensities of such a high order toward an approaching driver's eyes as to cause serious if not blinding glare. Further extensive test data prove that a properly designed lower beam will give adequate visibility when other cars are approaching, because of silhouette seeing—that is, seeing of vertical obstacles as dark patterns against the road lighted by approaching headlamps.

As a partially effective answer, therefore, to the exceedingly difficult headlighting problem, engineers have provided for two beams of light, a high one for the open road and a low one for use when meeting approaching cars and when driving on lighted streets or highways. The best technical solution currently available is the standard sealed-beam system developed cooperatively by automotive engineers and motor-vehicle administrators. On the upper beam this system provides good, clear road seeing for moderate speeds, and on the lower beam good relief from glare when meeting other cars and for urban operation. Many drivers, however, too frequently fail to depress their lights for approaching drivers and do not keep their lamps properly aimed.

Polarized headlighting.—The 1946 report of the Committee stated that polarized headlighting was being explored by automotive engineers working cooperatively. In 1947, the automotive industry advised the American Association of Motor Vehicle Administrators at whose request the work was originally undertaken, that a polarized headlighting system had been developed which could be used as the

basis for a commercial design. But the industry also reported that it would be impractical to convert the 35,000,000 motor vehicles then in service to the new headlighting and that the introduction of polarized headlighting on new vehicles would therefore be followed by a long period during which both the new and present headlighting would be in use. The industry stated that it foresaw many serious difficulties during this period of mixed use for which it could offer no satisfactory solutions and that consequently it recommended against the adoption of the new headlighting at that time. This recommendation was concurred in by the American Association of Motor Vehicle Administrators. The industry reports that nothing has developed in the intervening years to cause a change in its recommendations.

It appears impractical in a report of this kind to present the detail necessary for an understanding of polarized headlighting and the problems it presents. A detailed discussion, moreover, would be largely repetitious of information already published. Hence, those who desire more information are referred to Highway Research Board Bulletin No. 11.[17] This bulletin contains a paper on the subject by the inventor of Polaroid and President of the Polaroid Corporation, a discussion of the paper by the secretary of the industry committee which conducted the development program, and a report on seeing-distance tests by the technical staff of the General Electric Company.

Directional signals.—A cooperative program with motor-vehicle administrators has produced a standardized directional-signal system which is standard on some cars and optional on others. Reports indicate that the system functions satisfactorily. In the hands of a driver who uses it properly, it seems to be a desirable addition. It is no substitute, however, for good driving practices in making turns. Since the last report of the Committee two States have adopted laws making directional-signal equipment mandatory on all new motor vehicles. It is hoped that accident experience data in these States will help to clear up present uncertainties regarding the contribution these signals can make to safety.

Tires.—Tire and automotive engineers working cooperatively have effected tremendous improvements in tires from a safety standpoint. Progress in tread design has produced surer footing under unfavorable road conditions. The probability of blow-outs has been greatly reduced, though they still are a possibility which can have serious consequences, particularly when drivers lose control of their cars as the result of jamming on the brakes. Engineering effort on improvement in tires, wheels, and rims is being focused on further reductions in the

[17] **Published by the Highway Research Board, 2101 Constitution Ave., Washington 25, D. C.**

frequency of blow-outs and toward vehicle design that will make it easier for the driver to control the car when a tire goes out.

One development in this field is the butyl tube, now available on a wide scale. Tubes of butyl synthetic maintain inflation pressure longer than do tubes of natural rubber, which is advantageous both from the standpoint of tire life and safety.

Another advance in safety is the greater availability of rayon in the construction of tire casings. The development of synthetic rubber tires has advanced tremendously, and the combination natural-and-synthetic-rubber tires of today are safer than prewar tires of natural rubber.

Fast driving in hot summer months is a most severe test for tires. Owners should be informed that to insure maximum safety, proper inflation pressure must be continuously maintained and operating speeds must be held to a reasonable maximum to guard against overheating and possible tire failure. Overloading is another cause of overheating which, coupled with too great speed, multiplies the heating effect.

Reduction of noise and vibration.—Noise and vibration can distract and fatigue the driver and thus work against his ability to drive safely. Reduction of this factor is the object of continuing engineering effort. Examples of improvements include better balance of engines, insulation of engines with rubber mountings, gears cut more accurately for quietness, and reduction of cooling-fan and wind noises.

Steering and handling.—A great deal of progress has been made in steering and handling characteristics. This has brought easier steering, greater stability on turns, and correction of shimmy and tramp. Similar progress has been made in improving riding qualities, with consequent reduction in driver fatigue, and surer control where bumps and holes are encountered.

Simplification of controls.—The mechanics of operating the car have been substantially simplified. It is now possible for the driver to devote his attention more completely to safe operation. For example, with the old clash-type transmission, shifting, particularly to a lower gear, involved techniques that some drivers never mastered. This problem was solved by the synchronized shift. Other examples of simplification include change of location for the gearshift lever to the steering column, automatic transmission, windshield wipers and defrosters, foot switch for changing headlamp beams, headlamp-beam indicator, grouping of instruments on the driver's side, switch rearrangement, instrument-panel lighting, and push-button radio control.

Criticisms of Vehicle Design

The foregoing has reviewed briefly some of the automotive-engineering achievements responsible for the production of vehicles that can

be operated safely with reasonable care and without undue effort. The job is not finished. The engineer recognizes that the quest for safety is a never-ending one. In fact there is no danger that the designer will ever become smugly satisfied as long as the motoring public continues to exercise its right to criticize.

It would of course be surprising if some features of motor-vehicle design had not been the target of criticism from one quarter or another. Criticism is extremely valuable. It exerts more influence on design than many believe, when engineering knowledge and experience indicate that it is well-founded and where the advantages of the proposed design changes do not involve offsetting disadvantages. Among the features which have been criticized from a safety standpoint are the top speed of passenger cars, the low speed of trucks and combinations on hills, limitations on driver vision, and bumper design.

Top speed in passenger cars.—Passenger cars are powered to provide the high-gear acceleration and hill-climbing ability needed in the moderate speed ranges where most driving is done. Top speed is a byproduct of providing enough power to meet moderate speed-performance requirements. For several years average top speeds have shown no significant year-to-year increase. There is no present evidence that this trend will change.

Governors have been proposed to limit top speeds. Subjecting the driver to the control of an automaton in this manner would be undesirable from the safety standpoint, because if speed is arbitrarily limited, then when operating at the governed speed, the ability to accelerate out of trouble is lost. Governors are often installed on trucks, but these vehicles operate a much larger proportion of time in the lower gear ratios and governors protect the engine against over speeding in these gears. Even in these cases, however, they have also tended to encourage some drivers to coast downhill at dangerously high speeds in an effort to increase their average operating speed.

Low speed of trucks on hills.—The speed of trucks and truck combinations uphill is a function of gross weight and available horsepower. While it may be economically impractical to power commercial equipment to give passenger-car performance on hills, trucks currently have the power to operate uphill at well above the crawl speeds complained of, provided gross loads are kept in proper relation to available horsepower.

Limitations on driver vision.—Criticism of limitations on driver vision and other features of body design have been dealt with in the discussion of body improvements.

Bumper heights.—Bumpers present a problem that is not as simple as it may first appear. There is more to it than mounting bumpers at a standard height. The height of the bumper may vary momen-

tarily as much as 7 or 8 inches between acceleration and braking, thus aggravating locking. In addition, the problem of making the ends of the bumper proof against hooking cars, yet preserving its ability to absorb shocks, is not easy of solution. This matter has been the subject of study by the Society of Automotive Engineers which has issued a new standard for bumper heights to which new models are being designed.

Motor-Vehicle Inspection

An essential part of a complete safety program is statutory requirements for periodic safety inspections of the mechanical condition of motor vehicles in officially operated or designated stations. The purpose of periodic inspections is to discover any maladjustments in vehicles that might lead to accidents and, by correcting the maladjustments, to prevent accidents.

There are four major benefits from motor-vehicle inspection: (1) It improves the general standard of vehicle condition. (2) It affords opportunity to check motor and serial numbers actually on the vehicles against registration certificates, and in other ways assists in the enforcement of motor-vehicle laws. (3) It improves the quality of garage workmanship in making adjustments and repairs. (4) It provides excellent opportunity to inform drivers concerning the condition of their cars and their responsibility for driving safely 365 days in the year.

The laws of only 15 States provide for periodic inspection either through governmentally operated stations or through garages and service stations officially authorized to make these examinations. In some jurisdictions, inspection programs curtailed or discontinued during the war have been resumed, but in one State the current legislature has revoked the inspection law presumably because it caused inconvenience to some motorists.

The items to be checked in a well-operated inspection program, together with suggested standards, are itemized in the American Standard Inspection Requirements for Motor Vehicles.[18]

Table 8 lists some of the defects found in motor vehicles in the State-owned-and-operated inspection stations in New Jersey and in the stations owned and operated by the District of Columbia.

Whether inspections should be made through government-operated stations or through officially appointed garages and service stations is a moot question. Government-operated stations appear preferable, however, because they make possible a well-integrated, uniform program and obviate the commercial influences to which stations selling service are necessarily subject when making inspections. Further-

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[18] Published by the American Standards Association, 70 East 45th St., New York, N. Y.

TABLE 8.—*Some defects found in motor vehicles at inspection stations operated by New Jersey and the District of Columbia*

Cause of rejection	New Jersey—percentage distribution of rejections during—		District of Columbia — percentage distribution of rejections during—	
	1941	1948	1941	1948
	Percent	*Percent*	*Percent*	*Percent*
Lighting system	49.42	44.37	44.26	37.63
Brakes	27.63	28.04	15.46	19.98
Steering	8.83	12.08	9.74	14.03
Glass and obstructions to vision	3.20	6.36	4.64	6.60
Exhaust system	1.63	.82	3.54	3.11
Windshield wiper	1.58	.70	3.78	3.32
Horn	.55	.85	.74	.65
Mirror	.16	.40	.30	.20

more the contacts made by State inspectors can be a vital factor in impressing motorists with the need for safe operation of vehicles.

The exact influence of inspections on safety cannot be evaluated because they cannot be isolated from other factors affecting accident frequency and severity. There are no accurate statistics indicating the extent that maladjustments of vehicles are a contributing cause of accidents, and of course no statistics showing the number of accidents avoided because of the excellent condition of vehicles.

Statistics can be presented, however, indicating that inspections were a major factor in reducing accident and fatality rates. But they can also be presented to show improvement in these rates where no inspections were conducted.

State inspection services are not designed to, nor should they, supplant continual careful attention to the proper maintenance of vehicles, which is the moral and legal responsibility of all operators, both private and commercial.

Maintenance of Vehicles

From a safety standpoint the purpose of preventive maintenance is to preclude, by the continual application of suitable processes, the occurrence of accidents attributable to mechanical failure or malfunctioning of vehicle parts, regardless of whether failure or malfunctioning is (a) directly causative of such accidents, or (b) indirectly causative or contributory by reason of "road stalls."

Accidents involving vehicles of motor carriers and occurring in over-the-road operations when the vehicles are stalled because of some minor difficulty, are as severe in personal casualties and property damage as when the vehicles are moving and get into accidents by reason of failure of parts. This strongly indicates the importance of the readily preventable, seemingly minor faults, that cause vehicles to be stalled on the highway. To an extent, this is also true for private passenger cars.

Most operators of large fleets of busses and trucks practice preventive maintenance in the interest of safety and economy. The best preventive-maintenance and inspection procedure is one designed to determine what should be done and when it should be done to obtain maximum safety from each vehicle in service.

The most common measure of "when" is mileage. This may be most conveniently evaluated in terms of fuel consumption, time, or actual distance traveled, depending on the type of operation. However, vehicle design, operating conditions, loads, speeds, weather conditions, lubricants used, and other factors all have a bearing on when maintenance service should be given. With all these variables it is not practical or economical to attempt to set a definite mileage standard which will fit all operations.

A report, Preventative Maintenance and Inspection Procedure,[19] was prepared a few years ago by the Society of Automotive Engineers. It was designed as a guide for operators of all types of vehicles in all types of service, and as such can be adapted by each operator to his individual needs. If the adaptation of this program is carried out conscientiously, practical experience has shown that it will result in a material reduction of accidents due to mechanical failures.

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[19] Published by the Office of Defense Transportation, Washington 25, D. C.

RECOMMENDED ACTION PROGRAM

1. It is recommended that provision be made for continuous and intelligently planned programs of publicity, education, and law enforcement, without which the maximum benefits of engineering contributions to traffic-accident reduction cannot be obtained.

a. There is particular need to impress legislators and administrators with the fact that engineering standards cannot be translated into highway safety unless adequate funds and suitable engineering personnel are made available.

b. The education of persons of all ages in the safe use of vehicles, highways, and streets ranks high in importance. Engineering can accomplish much in accident prevention, but even with the finest possible engineering effort, the attitude and actions of individual pedestrians and drivers will still be prime factors in accident causation.

c. Particularly in this era of over-age vehicles, an urgent request should be made of every motorist to fulfill his fundamental, moral, and legal responsibility by maintaining his vehicle in safe operating condition.

d. In the field of formal education, more fellowships for traffic-engineering training at the graduate-school level should be provided at American colleges and universities. To the extent practicable, the teaching of traffic-safety-and-operation principles should also be incorporated in standard college and secondary- and elementary-school courses.

e. Intensive educational programs and conferences on traffic-safety-and-operation principles should be extensively conducted.

2. Within State and particularly within municipal jurisdictions, the efforts of many public officials and groups are directly or indirectly related to traffic safety. Examples of this distribution of interest are planners; housing officials; engineers of highway and street design, construction, maintenance, and operation; police; educators; and the various safety organizations and civic groups. There is genuine need for practical means for effectively coordinating the everyday and long-range safety efforts of these individuals and groups. It is recommended that appropriate administrative action be taken, particularly in municipalities, to bring about an effective coordination of traffic-operation-and-safety activities.

3. It is recommended that an effective and continuing liaison be established among motor-vehicle manufacturers, road builders, and operations engineers for the purpose of promoting closer coordination of (1) vehicle design, (2) geometric and structural plans for streets and highways, and (3) plans for operation. This liaison will have its maximum value if the participants are persons of high rank in the phase of highway transportation which they represent.

4. Traffic safety should receive greater emphasis in urban-redevelopment and new land-development plans. It is recomended that appropriate housing, planning, and engineering officials consider the traffic-safety features of all development proposals, and introduce wherever justified, added facilities or revised street and land-use plans that will promote safety. Cooperation among planning authorities and highway and traffic engineers can help to minimize accident hazards.

5. It is recommended that research in human and physical factors of traffic safety be greatly extended and intensified. Agencies able to conduct this research are urged to do so. The Highway Research Board of the National Research Council can suggest worthy projects and aid as a research "clearing house."

6. Highway planning surveys conducted cooperatively by States and the Federal Government provide the essential facts with which to develop long-range improvement programs to achieve safety. It is recommended that this important work be continued and expanded in urban as well as rural areas.

7. Recognizing that greater safety on the highway can be obtained by more extensive application of sound engineering and maintenance measures, it is recommended that trained engineers with proper experience be placed in the appropriate organization structures and given adequate remuneration, assurance of continuity in tenure of their positions, and reasonable opportunities for advancement.

8. In specific recognition of the need for better staffing of official agencies concerned with highway-engineering problems, it is recommended that there be established:

a. In each State highway department, a division responsible for the application of engineering measures in traffic operation and control. It should be comparable in authority to other principal divisions, such as design, construction, and maintenance. Employment in the design division of engineers trained in traffic-operation principles is also important.

b. In cities having more than 100,000 population, a traffic-engineering unit comparable in authority and influence to other major divisions of the department of public works or corresponding organization.

c. In cities having between 50,000 and 100,000 population at least one full-time traffic engineer vested with sufficient authority to insure the adoption of appropriate engineering measures for traffic operation and safety.

d. In cities having less than 50,000 population, an engineer—preferably the director of the department of public works, the city engineer, or some member of his staff—with qualifications and experience necessary to perform the functions of traffic engineer.

e. In county and other local street or highway departments required to handle traffic-operation-and-control problems of the magnitude of those of States and larger communities, an engineering service consistent with the above recommendations.

9. It is recommended that greater weight be given to traffic-engineering-and-safety considerations at the design stage of vehicles and highways. These considerations have, in the past, been subordinated on occasion to matters of appearance and economics. Safe utility of a vehicle or highway is best assured when safety features are built in at the time of construction.

10. It is recommended that State and local highway engineering authorities examine the system and forms of accident reporting and analysis in their jurisdictions for the value in dealing with high-accident locations and in improving street and highway designs. The engineer should cooperate with the agency responsible for collection and analysis of accident records to the end that additional facts or measures needed to increase the engineering worth of accident records will be provided. A competent, continuing engineering analysis of available accident data is recommended as a means of evaluating changes that result from various physical and traffic-control improvements.

11. It is recommended that diligent examination and study be made of all existing roads and streets to detect locations of undue hazard and to correct or improve conditions through application of the appropriate engineering or control measures.

12. It is recommended that definite provisions be made for the modernization of all principal highways and streets so as to furnish safe traffic-operating conditions for the foreseeable future. Recommended standards, policies, and guides have been developed after exhaustive traffic and engineering investigations, by the American Association of State Highway Officials, the Public Roads Administration, and other agencies.

13. It is recommended that sufficient width of right-of-way be acquired for modern construction, and that necessary control of access be provided on arterial routes, so as to reduce hazard, increase the ease of driving, minimize obsolescence, and protect the investment in the improvement.

14. It is recommended that improvements on secondary roads and streets be adequate for safe year-round use.

15. It is recommended that a combination of highway maintenance operations be so conducted as to provide a smooth, skid-resistant surface; safe, even shoulders; adequate drainage; and a clear right-of-way.

16. In recognition of the unusual hazards at railway and highway crossings at grade, it is recommended that these crossings be eliminated, with priority determined on the basis of hazard and economy of traffic operation. Where the construction of railway-highway separation structures is not feasible, provision should be made for adequate protection of existing railway grade crossings. Full and consistent use of the Federal funds authorized under existing highway acts of the Congress for railway-grade-crossing elimination and protection, is recommended.

17. It is recommended that every effort be made to continue and advance uniformity in roadway signing, signaling, and marking, in the design of roadways and structures, and in lighting devices and safety appurtenances required or used on motor vehicles. Administrative authorities are urged to follow the general standards recommended elsewhere in this report.

18. It is recommended that the basic principles of article VI, Act V, Uniform Vehicle Code, be adopted. Article VI provides for the establishment of speed restrictions and, among other provisions, authorizes speed zoning and prescribes separate day and night speed limits.

19. It is recommended that appropriate authorities adopt as a working standard the Manual on Uniform Traffic Control Devices prepared jointly by the American Association of State Highway Officials, the Institute of Traffic Engineers, and the National Conference on Street and Highway Safety. Revised in 1948, the manual contains recommended practice for the application, design, location, installation, and maintenance of highway signs, traffic signals, pavement markings, and islands. Substantial conformance with its provisions is required by the Federal-Aid Highway Act of 1944 on streets and highways built with Federal funds.

20. It is recommended that full use be made of all pertinent and available facts on traffic operation in the design, redesign, and control treatment of streets, highways, and vehicles. A guide manual of proved traffic-engineering techniques has recently been prepared by a Joint Committee on Street and Highway Traffic Engineering Functions and Administration, composed of officials of the American Association of State Highway Officials, the American Public Works Association, and the Institute of Traffic Engineers.

21. Traffic hazards can frequently be reduced by relatively simple or localized engineering treatments. The following are recommended as typical applications:

a. Use of raised median strips on wide, heavily traveled streets.

b. Use of adequate turning radii at intersections.

c. Intersection channelization.

d. Provision of additional lanes on grades for trucks and busses, and of special facilities for loading and unloading mass-transit vehicles.

22. It is recommended that plans be made for the provision of off-street parking facilities as the ultimate solution of the parking problem in congested metropolitan areas. These facilities should be designed and located with consideration for actual terminal requirements. Wherever possible they should have ready access to arterial streets.

23. It is recommended that the best possible use be made of curb parking space. Assignment of space for loading zones should be made in accordance with the determined needs so as to reduce double parking and similar hazards to a minimum. Angle parking should be discouraged. It may accommodate more cars along the curb than parallel parking, but it also creates greater hazard and interference with moving traffic.

24. It is recommended that sidewalks and other pedestrian facilities be provided on highways and streets when justified by the volume and character of vehicle and pedestrian traffic.

25. It is recommended that modernized street lighting be applied on main urban streets and on the more hazardous sections of highways, particularly near the entrances to municipalities where there is considerable pedestrian traffic. The American Standard Practice for Street and Highway Lighting, approved in 1947 by the American Standards Association, will be a helpful guide in this work.

26. It is recommended that surfaces of structures and other roadway elements be designed to take better advantage of vehicle headlighting to disclose their presence, dimensions, and position to the maximum extent practicable. Features of improved surface design

to be considered include color, texture, light-reflecting quality, area, and geometric position. Reflecting delineators are also helpful in the reduction of night accidents.

27. It is recommended that channelization be used more extensively to guide vehicles on a safe course through large-area intersections and to provide safe refuge points for pedestrians.

28. To increase further the protection afforded the pedestrian, additional facilities, such as loading islands, marked crosswalks, sidewalks, overpasses and underpasses, and barricades, should be constructed where pedestrian and vehicle volumes and roadway conditions warrant.

29. The principle of speed zoning, based on adequate factual investigation, is recommended for wider application. The practice of marking safe operating speeds on curves is especially commended.

30. It is recommended that the practice be discontinued of establishing low speed limits but permitting high tolerances in enforcement.

31. It is recommended that wherever practicable, additional use be made of the one-way street principle to increase street capacity and improve safety.

32. It is recommended that more consideration be given to the segregation of vehicles according to their traffic needs and performance characteristics. Movement may often be facilitated and operating hazards reduced by designation of through-street systems for the longer-range traffic and of certain streets, routes, or separate lanes for special classes of traffic, such as trucks or busses.

33. It is recommended that efforts be continued to improve all safety elements of vehicle design. Among the more important of these are driver vision, brake performance, vehicle lighting, and handling characteristics.

34. The limits of vehicle size and weight proposed by the American Association of State Highway Officials after ratification by a majority of the State highway departments, are recommended for general adoption.

35. In the interest of improving uphill performance of commercial vehicles, it is recommended that stress be placed on the maintenance of proper relationships between the gross vehicle weight of trucks and combinations and the horsepower output of their engines.

36. It is recommended that the manufacturer's authorized gross vehicle weight be used as a basis for the registration of trucks to control overloading.

37. It is recommended that there be strict enforcement of laws regarding overloading of commercial vehicles.

38. It is recommended that special attention be given to the design, manufacture, installation, and maintenance of brake mechanisms on the heavier vehicles so as to reduce, as far as feasible, the difference between the brake performance of these heavier vehicles and that of passenger automobiles.

39. It is recommended that improved mountings for external rear-view mirrors and spot lamps be developed to eliminate interference with driver vision, and continue a development trend already apparent.

40. It is recommended that immediate steps be taken to obtain uniformity in warning-signal-light systems on road-maintenance equipment, emergency vehicles, and the like, and on school busses particularly to notify motorists when the busses are stopped for loading and unloading. In standardizing these light systems, it is important to avoid conflict with present provisions of the Uniform Vehicle Code concerning other warning-light indications.

41. It is recommended that there be strict enforcement of laws concerning the use of lower beams from headlamps.

42. It is recommended that steps be taken to see that all car and truck dealers are equipped to give and promote adequate headlight service.

43. Statutory periodic inspection of motor vehicles is recommended, since it is an essential part of a complete safety program. Such inspections should be made in government-owned-and-operated stations.

44. With further respect to motor-vehicle inspection, it is recommended that the procedure employed be based on the American Standard Inspection Requirements for Motor Vehicles. Efforts to improve instrumentation for safety-inspection work should be continued.

45. It is recommended that steps be taken to develop reliable factual information to correlate accident causes with specific features of vehicle design.

46. It is recommended that there be no provision for limitation of maximum speeds by the compulsory use of governors.

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The final Conference-approved edition of this report will contain a complete list of the members of the Committee on Engineering.

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